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MATERIAL REQUIREMENTS PLANNING: A STUDY

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
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MATERIAL REQUIREMENTS PLANNING: A STUDY

by

AJIT S. KANODIA

Technical Report No. 128

Work Performed Under
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Operations Research Center
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November 1976

FOREWORD

The Operations Research Center at the Massachusetts Institute of of Technology is an interdepartmental activity devoted to graduate education and research in the field of operations research. The work of the Center is supported, in part, by government contracts and industrial grants-in-aid. The work reported herein was supported (in part) by the Office of Naval Research under Contract N00014-75-C-0556. Additional support was provided by the Defense Advanced Research Project Agency under Contract N00014-75-C-0661.

ABSTRACT

Inventory management techniques have gained in importance in the past few years because of the cash crunch being faced by most companies. Material Requirements Planning (MRP) is gaining rapidly in popularity, specially after the APICS (American Production and Inventory Control Society) MRP Crusade. The technique is being presented as if it were the cure for all ills. The purpose of this report is to identify a number of issues that are relevant to MRP and, wherever possible, to propose an approach. Another purpose is to study how firms tackle these issues and to present real-life implementation characteristics. With this in mind, seven firms were interviewed personally. The study concludes that the issues are largely unresolved in industry and whatever benefits are accruing are mostly due only to better timing information generated by the explosion process rather than any other formal procedures. It follows that further benefits are achievable if the issues are tackled in a scientific manner.

ACKNOWLEDGEMENTS

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Special thanks are due to all the people with whom I held discussions in the firms I visited for bearing with me while I subject them to numerous questions and for the information they provided. They must, unfortunately, remain anonymous.

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CHAPTER 1

WHAT IS MRP?

The following discussion assumes reader familiarity with MRP. A good description of MRP can be found in the book by Orlicky<45>. A glossary of terms can be found in COPICS (Communications Oriented Production Information and Control System) publication by IBM<13>.

MRP has been defined in the following terms: "A Material Requirements Planning (MRP) system, narrowly defined, consists of a set of logically related procedures, decision rules and records (alternatively, records may be viewed as inputs to the system) designed to translate a Master Production Schedule into time-phased net requirements and the planned coverage of such requirements, for each component inventory item needed to implement this schedule." (Orlicky<45>).

MRP is basically an information system. Looking at it from another point of view, it is a simulation technique by which we can simulate shop floor activity given a master production schedule. The logic and mathematics of MRP is essentially very simple - given the gross requirements for an item we net it out against the on-hand quantity to arrive

at the net requirements for the item, which is then offset by the lead time for the item to generate the timing information of when manufacture of this item should be started and hence when its lower level item should be available. When this is done through the entire product structure and for the entire master schedule we have a simulation of what the activities of each work centre should be at what time and when purchased items should be ordered and in what quantities. A single level computation can be schematically laid out as in Figure 1. Lot for lot lot-sizing has been assumed.

A few points that need to be noted are:

1. The explosion of the product structure described above is properly applicable to dependent demand items. The demand for an item is said to be independent if its demand is not a function of the demand for another item. The demand for an item is said to be dependent when its demand is a function of the demand for another inventory item.
2. The process has to start with a schedule that specifies how much we will manufacture in each period, for the end item. This document is the Master Production Schedule.

Lead time = 2 periods   Item A

Periods		1	2	3	4	5	6	7
Gross requirements		10	20	10	5		30	20
Scheduled receipts								
On hand	30	20	0	-10	-15		-45	-65
Net requirements				10	5		30	20
Planned-order releases		10	5		30	20		

Creates Gross Requirements
at the next level

Figure 1 MRP explosion illustrated.

3. To properly carry out the explosion process we have to know the stages the items go through. We also have to know information such as - for each unit of item A we need two units of item B and it takes one period to build it. Such information is maintained in the 'Product Structure' or 'Bill of Materials'.
4. To determine the net requirements for an item we need to know the on-hand quantity and scheduled receipts for that item. This information is maintained in the 'Parts Master' or 'Invantory Records'.
5. Once a 'Planned Order Release' is released it becomes an 'open order' and gets recorded in the 'Scheduled Receipts' row.
6. An inventory item can be a component of a number of end-products, in which case the requirements for the item are derived from the master schedules of all the end-products of which it is a component.
7. Using lot-sizing procedures, a number of net requirements may be combined into a single order in order to minimize inventory costs. Thus net requirements are an input into the decision making process.
8. An item may be a component at different levels in the structure of different or even the same item. To get around the problem this creates for efficient lotsizing

and explosion, a technique known as low-level coding is used whereby the lowest level at which an item occurs in the structure of any end item is identified. The item is processed only when that lowest level is reached in the level by level processing. (See Orlicky<45> page 63 for a detailed explanation.)

A schematic representation of an MRP system is given in Figure 2.

MRP in Perspective

A large number of functions have to be performed to support production related manufacturing application. The application areas that have been identified by COPICS are shown in Figure 3 which is a reproduction of Figure 2 from COPICS, Management Overview<13>. (COPICS is a set of eight manuals "that outline the concepts of an integrated computer-based manufacturing control system.") Of the 12 areas identified, Inventory Management happens to be one of them. It is in this area that MRP is applicable. Hence, MRP is only applicable in one of the twelve areas related to production - it is not a panacea for all production problems. Any claim that the Inventory Management subsystem is the most important subsystem is akin to saying that one particular transistor is the most important in an amplifier

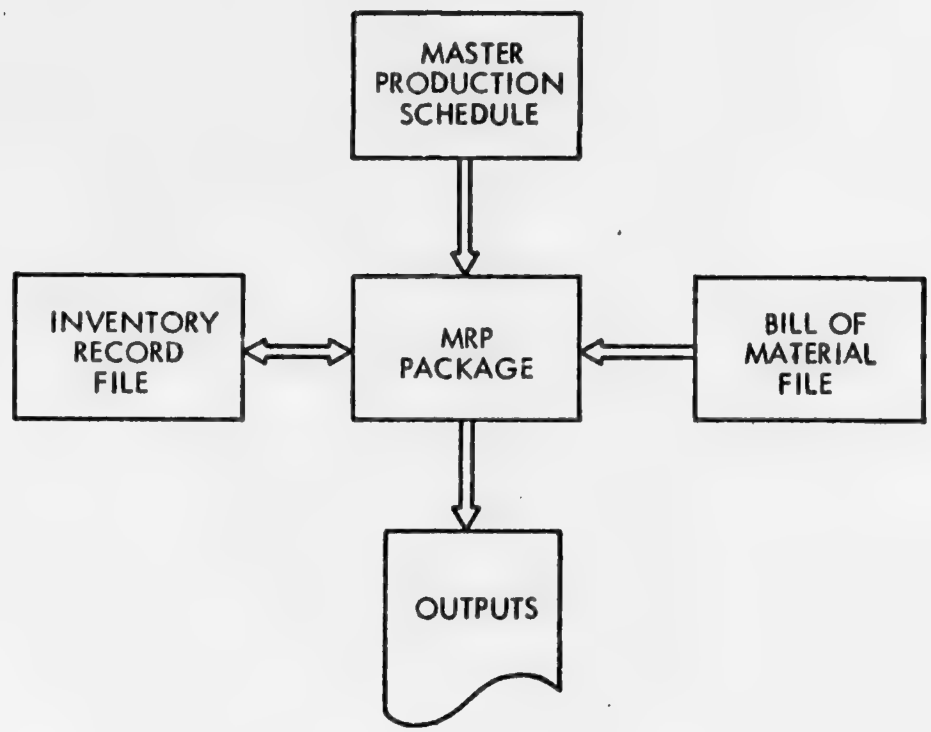


Figure 2 MRP schematic representation.

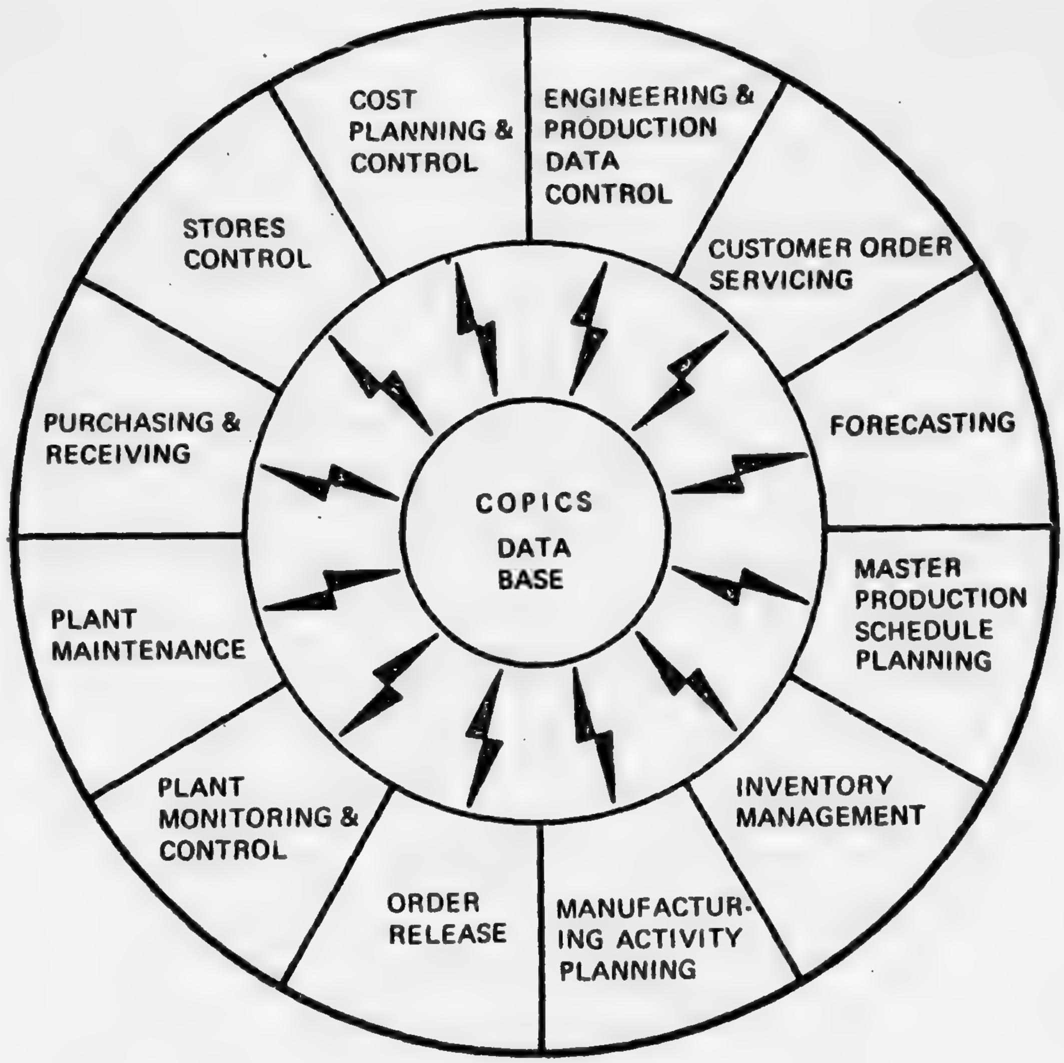


Figure 3 COPICS production related manufacturing applications.

circuit! The Inventory Management subsystem is as important as the other subsystems and the performance of any one subsystem depends on how well every other subsystem has performed. These dapendancies have been shown in Figure 4 which is a reproduction of Figure 23 in COPICS, Management Overview<13>. (The starred boxes are part of MRP.)

Another thing that should be pointed out is that MRP is an old concept that has been made possible by the computer and popular by APICS (American Production and Inventory Control Society). Only it was not called MRP then. Romeyn Everdell and Arnold Putnam in an article in Production and Inventory Management<55> mention an MRP like implementation some 20 years ago. As MRP becomes more popular older implementations may be revealed.

MRP is not a perfect technique. A number of issues still need to be looked into. Some of these are:

1. Where, why and how do we keep safety stock?
2. How do we set and control lead times?
3. Is there a need to freeze the master production schedule over the cumulative production lead time?
4. How do we master schedule?
5. Do we control every item by MRP?
6. Where, how and why do we lot-size?

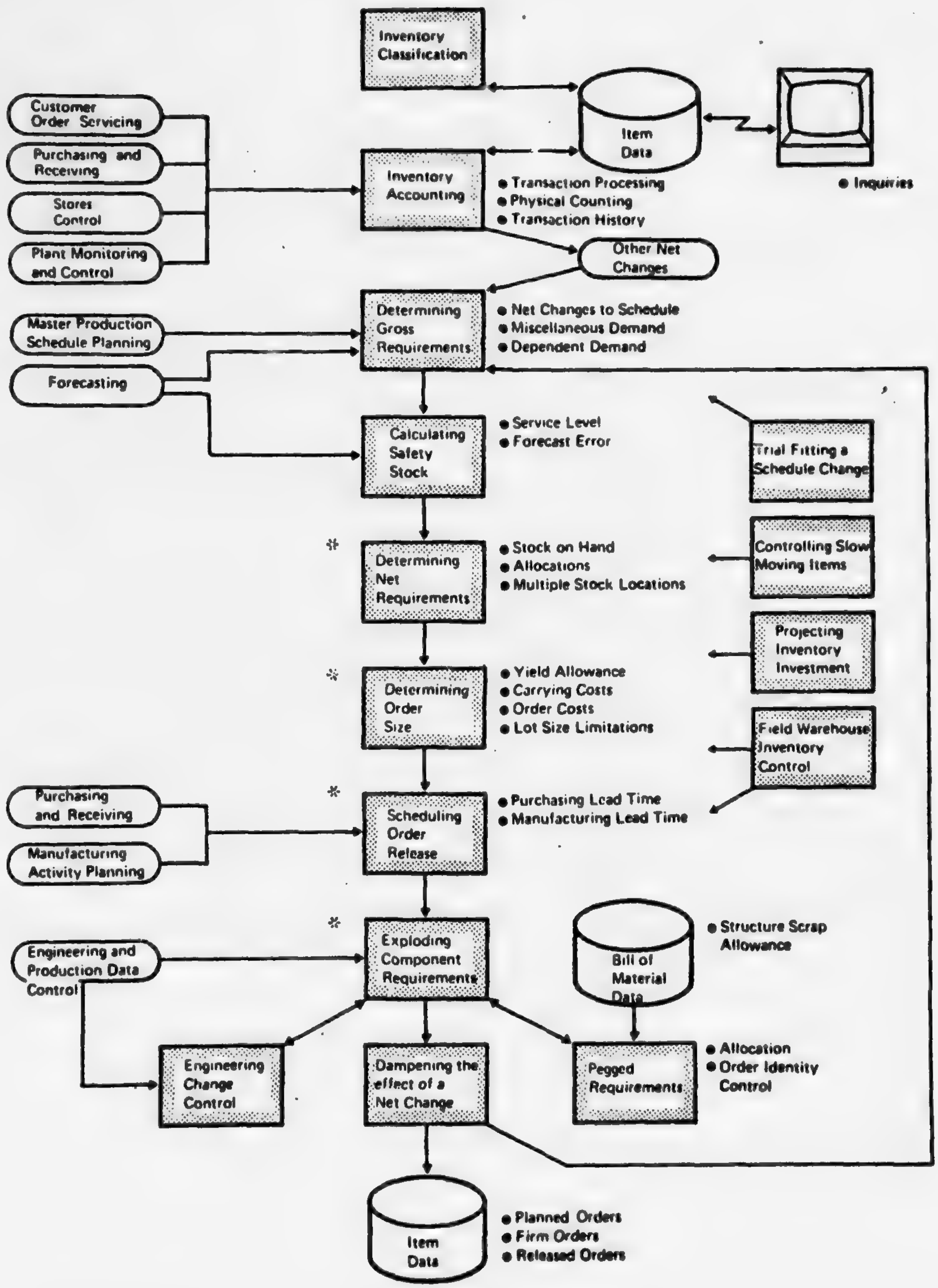


Figure 4 Inventory management functions.

We examine these points in the next six chapters in some depth.

CHAPTER 2

THE MASTER PRODUCTION SCHEDULE

Master production scheduling is the process of arriving at a master production schedule. A master production schedule is a documant that answers the following questions about the end items: What products should be produced? In what quantities should they be produced? When should they be produced?

Master production scheduling is an important function regardless of whether we use MRP or not. It is a co-ordinating function between manufacturing, marketing and finance - and sometimes engineering. Master scheduling is a decision making process that is both a threat and an opportunity.

MRP and Master Scheduling

The inventory management system has to operate within the constraints imposed by the master production schedule. In relation to MRP, master scheduling becomes very important because it is the prime and driving input into the MRP system. An MRP system is an infinite loading system. As Romeyn Everdell put it "An MRP system can explode anything -

and too frequently it does!".

MRP literature and Master Scheduling

It is an interesting observation that until recently master scheduling was not recognised in its importance to MRP and was considered to be something external. Somehow, it was assumed to be present. Amongst the first people to point out the importance of master scheduling in MRP was Romeyn Everdell<22> in 1972. Recently, this importance has become more and more recognised. Wight, in his book<69> says "The master schedule is to an MRP system as a computer program is to a computer". He also says "The design and management of the master schedule are recognised today as keys to the success - or failure - of an MRP-based system".

Despite this recognition, however, literature on MRP and master scheduling is singularly lacking. Numerous articles were published on MRP in Production and Inventory Management during the APICS MRP Crusade - but not a single one of them was on the topic of master scheduling to the best of my knowledge.

Existing literature does little more than point out that the master schedule has to be feasible. Wight<69> says "The master schedule cannot be overstated or priorities will become invalid". No formal procedures are provided to help

arrive at a feasible schedule and to check the feasibility of such a schedule.

Feasibility Management - an Aid

We present a techniqu to manage the master schedule to a feasible schedule.

Suppose a firm plans to produce certain quantities of certain products at different times. In terms of production capacity, what impact does the plan have? The problem is best viewed in terms of a three dimensional matrix as in Figure 5.

For each product the firm makes, it maintains routing information. Thus, for product P7, the routing file tells us that the processing takes place in work centres W1,W3,W4,W5 and W6. The routing file also contains the sequence of operations and lead time information such as setup time and standard work-centre requirements (in terms of man-hours, dollars or some other unit). We thus know that in order to produce X17 units of prodect P1 in time T7, we need L171 units of capacity at work centre W6 in time T1, L172 units of capacity at work centre W4 in time T2 etc. The matrix can be completed in this fashion for every product - time combination (such as X17) planned.

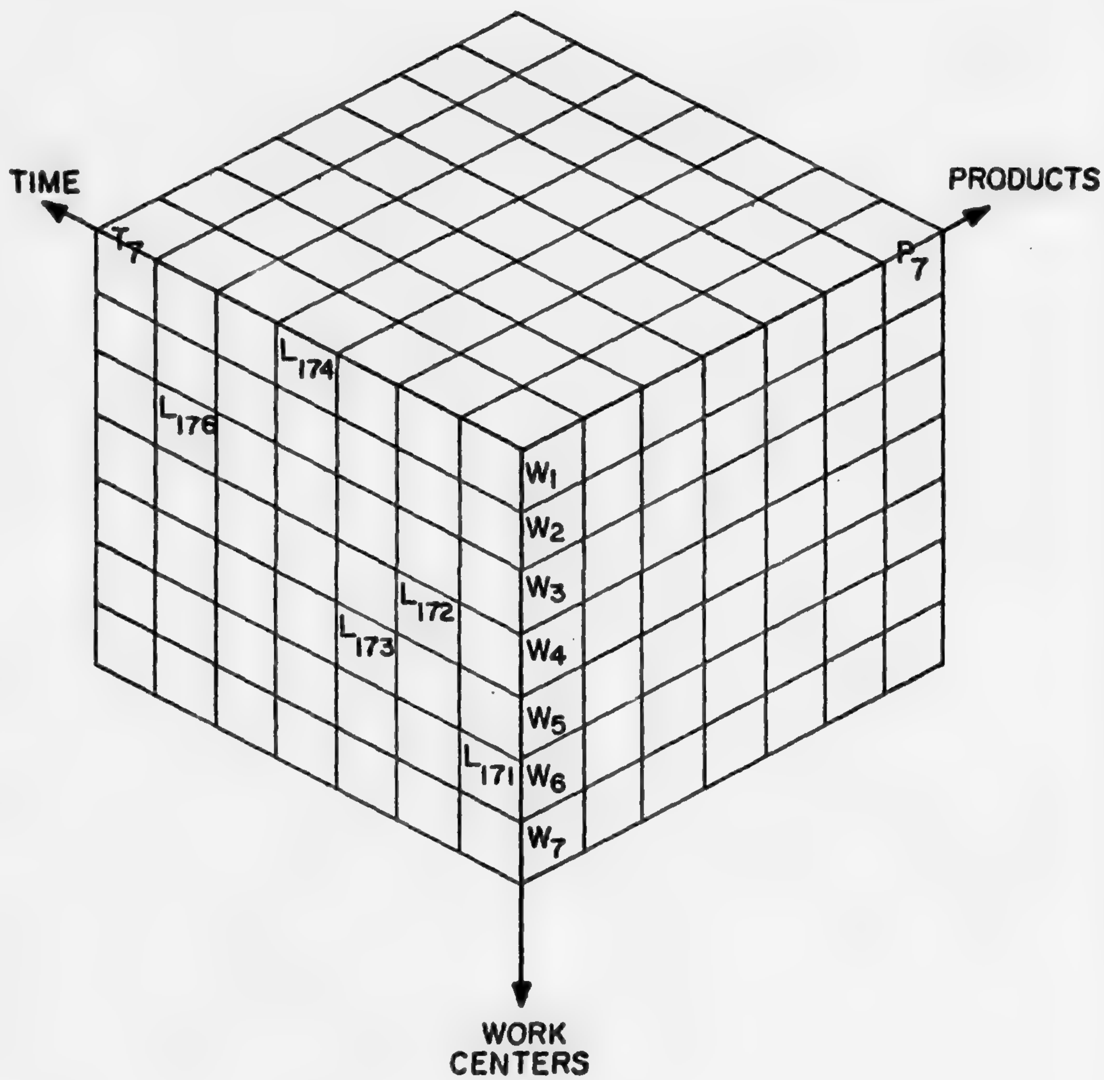


Figure 5 Product - time - work centre matrix.

We can now take cross sections along the different axes to come up with useful information. First, let us consider a horizontal cross section i.e. consider all the information for a given work centre, say W_1. If we sum the capacity requirements of all the products by each time unit, we get a load profile for the work centre. This may look as in Figure 6. When we superimpose on the plot the planned capacity, we can see at a glance that the work centre will be overloaded at times and underloaded at other times.

Next consider a vertical cross section parallel to the product-work centre plane. This gives us information about the capacity requirements in a given time unit at the different work centres generated by all the planned products. A typical plot is shown in Figure 7.

Lastly, consider a cross section parallel to the time-work centre plane. This gives us the load profile at different work centres generated by a product. A typical plot may look as in Figure 8.

All of these plots provide useful information and will help us keep our master schedule feasible. In order to achieve this, the following steps need to be carried out -

(i) Aggregate the products into product groups. All the products in a group have similar routings. At an

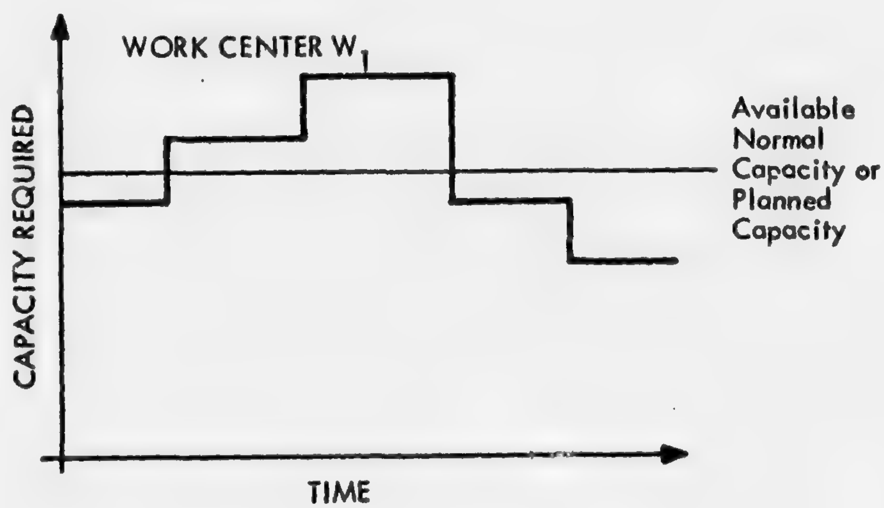


Figure 6 Work centre load profile.

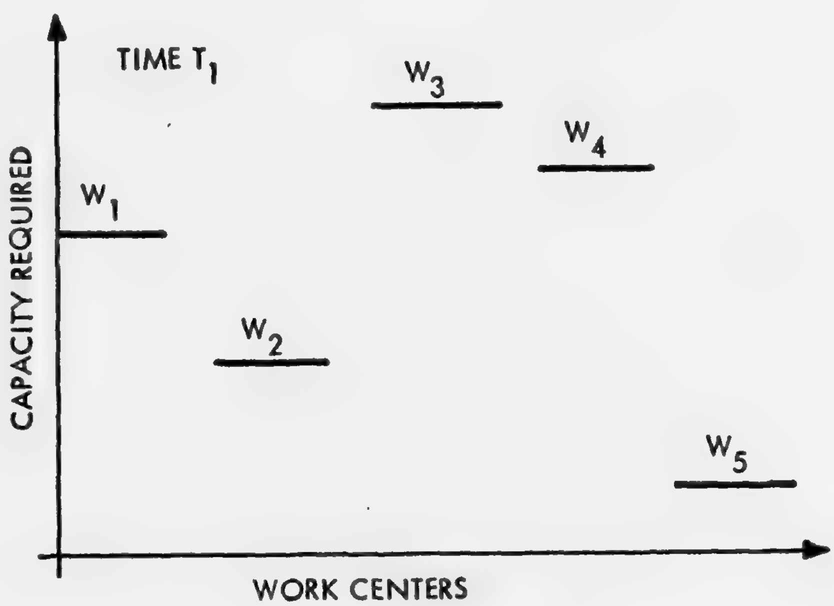


Figure 7 Time load profile.

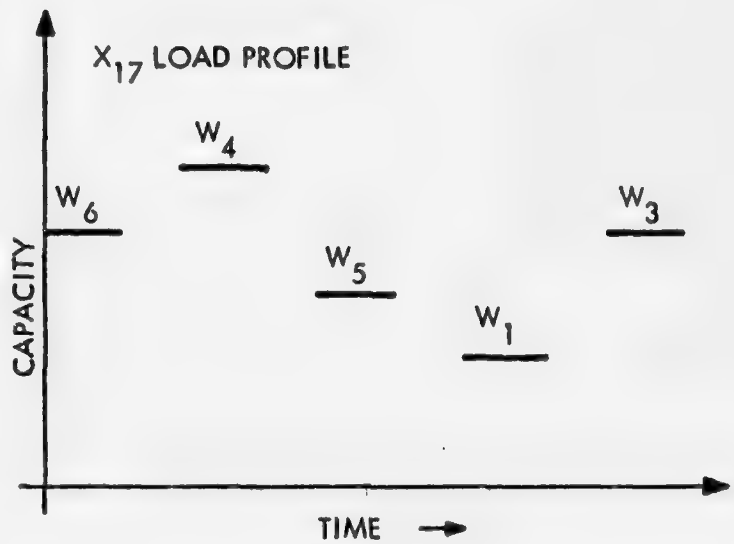


Figure 8 Product load profile.

aggregate level we will schedule for the product groups. Thus all diffusion pumps would be in one product group, all mechanical pumps could be in another etc. This has to be done very infrequently.

(2) For each group, define a 'unit' which provides a meaningful load and in whose multiples we will be dealing to arrive at initial guidelines. Thus, for diffusion pumps the 'unit' might be 5 pumps. For a small electronic instrument the 'unit' might be in 100's because 5 instruments do not provide a meaningful load and we schedule only in multiples of hundreds.

(3) For the 'unit' of each product group, generate a load profile at different work centres created by the 'unit'. This load profile is similar to the one shown in Figure 8.

(4) Based on sales forecasts and strategy, arrive at the ratios in units at which you would like to produce. Such a ratio might be 2:1 for diffusion pumps to mechanical pumps. Thus for each 'unit' of a mechanical pump we would like to produce 2 'units' of diffusion pumps. Based on probability estimates, we may arrive at 2 or 3 such sets of ratios.

(5) For each set of ratios and using the load profiles, it is easy to arrive at absolute numbers of maximum units for each product group that we can make in any one period.

All the steps outlined so far are performed very infrequently. The next few steps are much more frequent.

(6) When arriving at a master schedule, the first step is to arrive at aggregate numbers by groups. (This procedure being described is only one to help keep the master schedule feasible in an easy and systematic way - it is not a master production scheduling technique.). These aggregate numbers must lie within the upper bounds computed in step 5.

(7) Items within a product group can be in any ratio so long as their sum does not exceed the group total.

(8) Once a detailed schedule is arrived at within constraints 6 and 7, it is exploded using MRP. This process generates for us detailed load profiles at every work centre.

(9) Compare these detailed profiles to actual capacity. It may be possible to absorb small excesses and imbalances. This is a decision production people have

to make on reviewing the loads.

(10) Significant imbalances that cannot be absorbed have to be reconciled by cycling back and changing the master schedule. Once again we are helped in this by the load profiles of step 3.

Should significant imbalances occur regularly it means that (a) product groupings be re-examined and (b) the load profiles be re-examined for accuracy.

A schematic diagram of the more frequently performed steps (step 6 onwards) is given in Figure 9.

Modelling Approaches to Master Scheduling

There are a number of modelling approaches to master scheduling available in literature. In the following pages we present some of these models and comment on their relevance in the context of MRP.

(a) Linear Programming models

These are linear and quadratic cost models which can be subdivided into fixed and variable work force models. Classical models are the ones proposed by Bowman<10>, Hanssmann and Hess<28> and Holt, Modigliani, Muth and Simon<30>. These models are easy to solve using linear

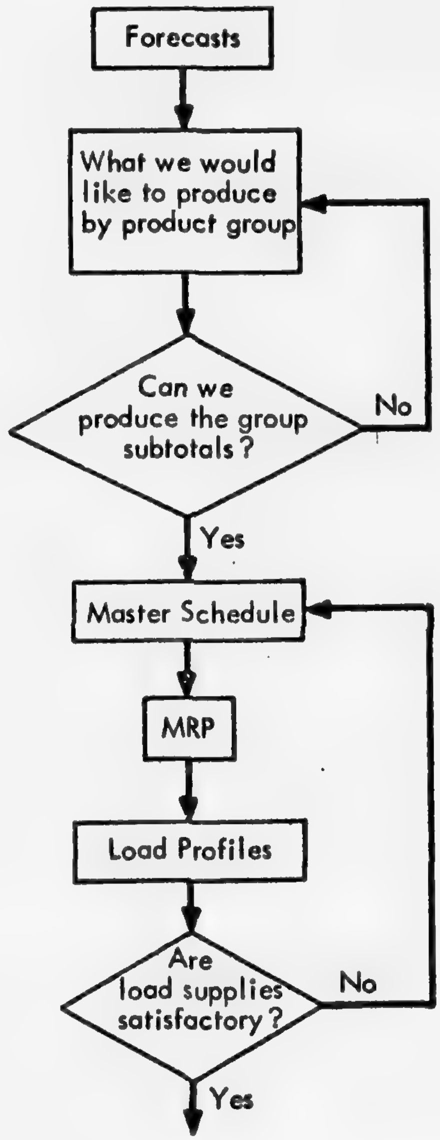


Figure 9 Feasibility management flowchart.

programming techniques. However these models

- ignore setups
- ignore details such as work centre capacities
- ignore lot-sizing at intermediate levels
- ignore multi-stage considerations
- require aggregation of end items into product groups
- this means that we have to disaggregate to arrive at a detailed schedule

(b) Lot-Size models

These models take into consideration the setup costs involved. Because of this and lot size indivisibility these models become

- large scale
- integer
- nonlinear

These models are multiproduct models but are also single-stage and so intermediate stages are not considered.

Manne<37> reformulated the capacitated non-linear lot-size model as a linear program. The rasultant model was computationally infaasible due to the large number of equations. Methods to overcome these difficulties were proposed by Dzielinski and Gomory<19> and Lasdon and Terjung<34>.

There is a set of models for multi-stage problems that allow for an item to have multiple predecessors (a predecessor is an item that goes into another item) but only a single successor (a successor is an item into which another item goes). Also, all these models are uncapacitated in that work centre capacities are not considered in arriving at the optimal lot sizes. These models also deal with only a single final product.

Schussel<57> has developed a simulation model and heuristic decision rule while Crowston, Wagner and Williams<14> have developed a dynamic programming algorithm. Both these assume that the lot-size at a stage is an integer multiple of the lot-size at the succeeding stage in an optimal solution. Crowston, Wagner and Williams<14> prove that under certain assumptions of constant continuous final product demand, instantaneous production, infinite planning horizon and time invariant lot sizes the 'integer multiple' assumption is correct.

In another paper Crowston, Wagner and Henshaw<15> showed that heuristic routines do as well as the dynamic programming model with less computation time.

Lanzenhauer has developed a couple of models for the general case of multiple products with multiple predecessors

and successors. One of these<26> is a mathematical programming model and the other<27> is a bivalent linear programming model. Unfortunately, these models are as yet infeasible.

(c) Hierarchical models

These models attempt to provide an integrated approach to level by level decision making with a view to avoid suboptimisation. Using this technique, decisions made at higher levels provide constraints to lower level decision making. At each step a different mathematical model is used.

Models have been suggested by Hax and Meal<29>, Bitran and Hax<9> and Armstrong and Hax<3>. The approach used is to divide items into three levels - Items (the final product), Families (groups of Items that share a common setup cost) and Types (groups of Families with similar costs per unit of production time and similar seasonal demand patterns). Aggregate production planning is done by Types and the results are then disaggregated.

However, these models are also single-stage models and hence not directly applicable in the MRP context.

CHAPTER 3

FROZEN PRODUCTION SCHEDULE

Consider the requirements plan shown in Figure 10.

The product has a cumulative lead time of 7 periods. Consider now that everything is proceeding according to plan until period 5. In period 5 we wish to revise the master production schedule for net requirements in period 9 based upon recent information. Can we do this? Consider the problems we have to face in order to be able to do this.

1. Based on the forecast requirements in period 9 we have already started the assembly process for the lower level items in order to be able to satisfy the period 9 requirements. Thus item C has already been made and item B is in the process of being assembled in a planned quantity to a planned schedule. If we now decide we want to increase the master schedule then an additional quantity of item B has to be made available somehow by period 6 when the assembly of item A begins. An additional quantity of B can be made available only if more C is produced because item C goes into the production of item B. However, we have only one period in which to achieve all this.

Lead time = 1 End item 2

	1	2	3	4	5	6	7	8	9
Net requirements									20
Planned-order releases								20	

Lead time = 2 Item A

Gross requirements								20	
Scheduled receipts									
On hand									
Net requirements								20	
Planned-order releases						20			

Lead time = 2 Item B

Gross requirements						20			
Scheduled receipts									
On hand									
Net requirements						20			
Planned-order releases				20					

Lead time = 2 Item C

Gross requirements				20					
Scheduled receipts									
On hand									
Net requirements				20					
Planned-order releases		20							

Figure 10 Time-phased requirements plan

2. If we want to reduce the master schedule then we have the problem of already having produced item C in quantities greater than actually needed. We will thus have excess of lower level items. Also, we will have unutilized capacity unless we can find some other item for production - and this is unlikely since by its very nature MRP makes items available only according to plan - or we are lot-sizing and producing not only for today but for future needs as well.
3. An increase in master schedule will tend to upset the shop load balance which was achieved using the original master schedule.

All these factors lead us to the conclusion that the master production schedule has to be frozen over the cumulative lead time when using MRP. There is a certain amount of flexibility, however, and it is provided by the following factors.

1. If a number of the lowest level items are items of common usage then the length of the frozen horizon can be reduced by the cumulative lead time of these common usage lowest level items. This is because we assume that increases and decreases in the master schedule are equiprobable and will tend to cancel out.
2. The aggregate total of production quantity is more

critical than the quantity of any one time period alone. Thus, if two adjacent period net requirements at the master schedule level were 100 each then it is easier to cope with changes that make the master schedule 110 and 90 or, 90 and 110 rather than 110 and 100. This is easy to follow if we imagine the addition of a net requirement of 20 in period 10 in Figure 10. If now in period 5 we want to change the master schedule to 25 in period 9 and 15 in period 10 then how do we meet the increased requirement of period 9? What makes this problem less difficult is the fact that we will have the required number of item C because item C has been completed in a lot of 20 for period 10's demand! Hence the problem is less severe.

3. As discussed in the chapters on safety stock and lead time, we can engage in expediting activity if capacity is available. Hence, at work centres not being run to capacity, we can still tolerate changes.
4. Again as discussed in the chapter on safety stock, we can provide for changes in the master production schedule within the cumulative lead time to the extent that we maintain safety stocks to tackle such uncertainty.

MRP is hence most useful when the master schedule can

be frozen over the cumulative production lead time. There is a little flexibility available but that is mostly due to capacity.

Otherwise MRP can be viewed as an information system or a simulation technique that can warn us in advance of what the likely effects of changes are. It can give us useful information such as "you can do this provided you are willing to delay requirement X or requirement Y".

Many firms do have some of these flexibilities and change the master schedule within the cumulative lead time. It is important that such firms know where their strengths lie in order to allow such changes. Equally, it is also important for firms that do not have these flexibilities to be aware of the need for a frozen schedule.

CHAPTER 4

SAFETY STOCK

Safety stock is needed to safeguard against uncertainty. Uncertainty may be of many types.

(1) Uncertainty in demand of the end product

(2) Uncertainty in demand of intermediate items

(a) if they are service items

(b) if we allow the master production schedule to be changed within the cumulative lead time

(3) Uncertainty in lead time

(4) Uncertainty in supply caused by variability in yield due to scrap and productivity.

These uncertainties will be present regardless of the inventory management system in use. Let us examine the uncertainties in greater depth.

(1) Uncertainty in demand of the end product

If the firm makes to order or makes only to backlog then there is no uncertainty in the demand for the end product. However, most firms do not have these luxuries and

they make to forecast. Hence uncertainty is present because the actual demand may be different from the forecast demand. In the context of MRP, how is this taken care of?

The only way this can be taken care of is by maintaining safety stock for the end products. This is true regardless of whether we use MRP or reorder point. This safety stock is based on estimated forecast errors, lead time and service level.

One technique for maintaining this safety stock is the time phased order point. Let us see what this technique is and how it works.

Consider an end item (level 0 item) X. Item X has the following characteristics.

Cumulative lead time = 3

Safety stock = 100

Consider the Figure 11. It shows the master production schedule and the on hand quantities. We have also shown the master production schedule to be frozen over the cumulative lead time. However, whether we freeze the master production schedule or not will only affect the quantity of safety stock we want to maintain, the rest of the technique is basically unchanged.

Period	1	2	3	4	5	6
On hand (Safety stock) 100	100	100	100	100	100	100
Master Production Schedule	20	15	35	15	10	20

← Frozen →

Figure 11 A frozen production schedule.

If everything goes as planned and our actual sales are matched by the quantities produced, we are in good shape. However, suppose the demand in period 1 actually turned out to be 35 units as compared to the forecast demand of 20 units. The additional 15 units are made available from out of the safety stock which will hence fall to 85 units. Our safety stock has been computed based on variability over the lead time of 3 periods. Hence we expect to match variability over the 3 periods out of safety stock. Beyond that, however, we should be back at the level of 100 units. Hence, the affect of the additional demand is shown in Figure 12.

Note that the master production schedule has been increased in the first period outside the frozen horizon.

Normally the master production schedule does not vary as forecast demand does. Instead, the on hand inventory is the shock absorber and the master production schedule is made smooth. In such cases, the only difference is that the on hand quantities will usually be larger than the safety stock. However, as soon as the on hand inventory falls below the safety stock, the master production schedule is updated beyond the frozen horizon so that the safety stock be brought back to normal at the end of the frozen horizon - and the safety stock has been calculated to take care of

Period		2	3	4	5	6
On hand (safety stock)	85	85	85	100	100	100
Master Production Schedule		15	35	15+ 15	10	20
		← Frozen		→		

Figure 12 Changes within the frozen production schedule.

fluctuations within the frozen horizon anyway. (The technique is the sama for those who believe they have to freeze the master production schedule over the cumulative lead time and those who believe it does not have to be frozen for such a length of time. Everyona agrees it has to be frozen over some length of time - hence the use of the term frozen horizon.).

Earlier we mentioned that if you believe that you do not have to freeze the master production schedule over the cumulative lead time then you could do with a smaller safety stock. The belief that you do not have to freeze the master production schedule over the entire cumulative lead time springs from the ballef that you can rush through an order in less time than the cumulative lead time. Even if this were true, however, it is not racommended that safety stock be reduced. After all, safety stock is there for production convenience and it does not make much sense to rush through an order just to bring the on-hand inventory back to a certain level. Hence, regardless of whether the master production schedule is frozen or not over the cumulative lead time, safety stock should be calculated as if it were frozen. Also, safety stock should be replenished in the normal course of action by increasing the master schedule beyond the cumulative lead time - a rush order should not be

placed, otherwise the whole purpose of the safety stock is defeated.

Calculating the Safety Stock

MRP poses no special problems that might need new techniques for calculating the safety stock for the end item. Conventional techniques are applicable here too. Thus, depending on the service level desired one might calculate safety stock as

Safety Stock = factor * MAD

'factor' depends on the service level

MAD = Mean Absolute Deviation of the forecast error over the cumulative lead time.

(2) Uncertainty in demand of intermediate items

(a) Service items

Demand for items that are also service items is made up of two components.

(1) Dependent demand arising due to demand for higher level items. This is tackled as all other dependent demand is by MRP.

(2) Independent demand due to service requirements. This should be tackled just like the independent demand

end items are, as explained above. Hence, for these intermediate items we maintain a safety stock. This safety stock is calculated based on the cumulative lead time, exactly as for the end products.

The independent demand is added to the gross requirements generated as dependent demand and the sum is netted against on hand inventory.

(b) <u>Changes in the Master Production Schedule within the cumulative lead time</u>.

Inasmuch as the master schedule is frozen over the production lead time and the item has no service requirements, the demand for all intermediate level items is determined with certainty. However, if we allow changes in the master schedule within the cumulative lead time then the demand becomes uncertain - depending on whether there is a change or not.

If the change is a reduction then we do not need any stock to meet it - in fact we create stock. If the change is an increase in the quantity desired then depending on the timing relationships one of two things might happen.

(i) the item may have already been produced or is in the

process of being produced to the previously determined demand. In this case the desired increase has to somehow be made available. This can be achieved in one of two ways.

(i) rush through an order - expedite it. This may be possible if capacity is available. This point is discussed in Chapter 3.

(ii) maintaim a safety stock to cover such increases in demand.

(2) the full lead time is still available to produce the item but the quantity to be produced has gone up. Once again if capacity is available then the extra quantity can be produced and the lead time maintained. If capacity is not available then safety stock will be needed.

We therefore see that the issue whether safety stocks are needed at intermadiate levels or not due to the type of uncertainty being discussed depends upon the capacity limitations.

If we stick to the scheme of time phased order point and safety stock for the end items, however, then the issue discussed above does not arise. Any changes in quantity are

taken care of by the end item safety stock. Safety stock at the end item level owes its very existence to the presence of such variability!

(3) <u>Uncertainty in lead time</u>

Lead time uncertainty may exist at two places.

(a) purchased items

(b) manufactured (assembled) intermediate items

(a) <u>Purchased Items</u>

Here we are dealing with an interface between MRP and the outside world. There is no guarantee that vendors will supply items based on an exact lead time. Experience shows that this lead time varies. At the plant level, we must develop a technique to counteract this variability. Two possibilities exist.

(i) Fixed Quantity

Using this technique, we keep a fixed quantity of purchased item on hand as safety stock. Thus, if the purchased item is late in arriving we issue parts from the safety stock.

Demand for low level items is, however,

lumpy. Lot sizing makes this demand even lumpier. For purchased parts the demand might be lumpy or not depending in the number of end items it goes into. If the part or material is common to a number of end items its demand may tend to smooth out. However, if demand is lumpy then the question that arises is how large should the fixed quantity safety stock be?

One answer is that the fixed quantity should equal the largest expected one period demand after lot sizing. This will result in a lot of safety stock in terms of item-periods. If orders come in on time then we carry the fixed quantity forever. If orders are late then part of the fixed quantity is carried because the fixed quantity is based on the expected maximum. Hence in this technique the safety stock is not related to the order quantity.

(ii) Safety time

Using this technique we place the order for the purchased parts one safety time unit ahead of what is indicated by our requirements based on a given lead time. Thus we plan to have the parts on hand one safety time unit before we really need

them. In this way we cover ourselves for adverse variability in lead time of upto one safety time unit.

Here the safety factor is related to the order quantity in the sense that we are expecting the order quantity.

Just as we used the concept of MAD in computing the safety stock at the end product level, one can use it to calculate the safety time for purchased parts. We can compute the MAD about the expected lead time over a number of observations and use a safety time of (factor*MAD) where "factor" depends upon the service level we wish to achieve.

Also, the lead time should be monitored in order to arrive at a better expected lead time. This can be done by means of a smoothed-error tracking signal as suggested by Brown<11>. The smoothed error z is an estimate of the average algebraic arror and is computed as

z(t)=h*a(t)+(1-h)*z(t-1) where h=smoothing constant

e(t)=x(t)-x1(t), x(t)=actual lead time

xi(t)=forecast (planned) lead time

The mean absolute deviation MAD(t) is also smoothed as

MAD(t)=h*|e(t)|+(1-h)*MAD(t-1)

Then if the ratio of |z|/MAD gets large it is an indication that the lead time estimate needs to be revised.

Clay Whybark and Greg Williams<65> conducted a simulation to test the hypothesis that there would be a 'preference' for either safety lead time or safety stock under four categories of uncertainty - demand uncertainty and supply uncertainty each further divided into quantity uncertainty and timing uncertainty. In their conclusions they say

"Under conditions of uncertainty in timing, safety lead time is the preferred technique while safety stock is preferred under conditions of quantity uncertainty. These conclusions are not dependent on the source of the uncertainty (demand or supply), lot sizing technique, lead time, average demand level, uncertainty level or coefficient of variation.

These experiments indicate that as the coefficient of variation and uncertainty levels increase the importance of making the correct choice between safety stock and safety lead time increases."

Other techniques for lead time analysis are presented by Collier<12>.

(b) Assembled intermediate items

In a job shop, the lead time at any work centre is a function of the total load on the work centre and its production rate. If the work centre is running below capacity then the total lead time can be increased and the lead time still be maintained constant by stepping up the production rate. As we approach the capacity, however, the flexibility is reduced.

Hence for a work centre running close to capacity, the lead time can vary depending on the load. If load is allowed to get too large, lead time becomes greater than the planned lead time. Hence the presence of lead time uncertainty.

It is important here to realise that capacity

is the crux of the problem. We can change the lead time of a job if it is a high priority job - by pulling it through first. However, this can be done only at the expense of another job i.e. by deexpediting some other job - if we are running to capacity. Hence the argument that lead time depends on priority does not hold. The central issue is one of capacity. In the face of capacity constraints the whole game of pulling a job through by giving it high priority will backfire. This is so because by expediting one job to get it done on time, we will have to expedite yet another to have that done on time (because we have effectively deexpedited it). Very soon we will be unable to get a job done on schedule no matter how high a priority you place on it and all the other jobs in the shop will be hopelessly behind schedule.

Where does all this lead us to? The answer is that it depends on the situation. If the shop is being run below capacity there is no problem. If the shop is being run near capacity and there is strong control on input once again lead times can be maintained. If there is no input control,

however, then we have to start worrying about lead time uncertainty.

Given lead time uncertainty, how do you tackle it? Once again two methods suggest themselves.

(i) Fixed quantity

Using this technique we keep a fixed quantity of safety stock at each work centre where the problem exists. Then if the lead time gets longer than planned, the safety stock is utilised. The safety stock is automatically replenished when the order that is late comes through.

The quantity of safety stock to maintain has to be computed for each work centre separately. This is a difficult question to answer and depends on the density of orders due and increase in lead time. Consider the following situation at a work centre. Two jobs are scheduled to finish in periods 10 and 11 respectively. The planned lead time is 6 periods. Suppose actual lead time for both the jobs goes up to 8 periods. Hence they will only be completed in periods 12 and 13 respectively. Therefore we should have enough

safety stock to cover for both the requirements. If, however, the jobs were due initially in periods 10 and 12 and the lead time increased by 2 periods than they will actually be completed in periods 12 and 14. In this case less safety stock is needed because the earlier requirement becomes available by the time the next requirement becomes due.

The amount of safety stock needed is -
(the number of jobs due within the increased lead time)*(an estimated maximum per period dependent demand)

(ii) Safety time

Adopting this technique we plan to have the job completed a safety time ahead of when it is actually needed. Hence if the lead time goes up by upto as much as the safety time, the job will still be completed by when actually needed. Once again the cascade effect has to be taken into consideration. To follow this, consider two jobs due for completion in periods 8 and 10 without provision for safety time. Note that it needs 2 periods after the first job is complete to

complete the second job. Now let us provide for safety time of 1 period. Then the jobs are due for completion in periods 7 and 9 respectively. Suppose the job due in period 7 cannot actually be completed until period 8, due to increase in lead time of 1 period. Following this, under normal circumstances the next job would be completed only in period 11 despite the 1 period safety time. This is what is meant by the cascade effect and it makes the safety time calculation similar to the fixed quantity safety stock computation.

There is not much to choose from between the two techniques. Each one has its disadvantages. In either case we are lying to the system. In one case we do not really need an order to be completed so early - the foreman merely sees his job sit at the next stage after completion and tends to switch to his informal system of priorities. In the other case we do not need so much to be completed and the same situation occurs. Hence both techniques have psychological and administrative drawbacks.

However, between the two we would choose the fixed quantity technique. This is because for the

next type of uncertainty discussed we use something akin to fixed quantity because we are concerned with quantities rather than timings. Hence there will be a certain amount of consistency which should help make system design easier. Also we will avoid the situation where an intermediate product might be subject to both timing and quantity aspects of safety stock.

Besides, the multi level effect should be considered. Using safety time at a level means that all the levels below it are also forced to work by the safety time. Thus safety time is visible through all the lower levels of the product structure. This problem does not arise for fixed quantity safety stock. This problem also did not arise with purchased material because there are no lower level items that can be affected. (The earlier cited reference work by Clay Whybark and Greg Williams<65> did not consider the effects of part commonality and multiple levels.).

(4) <u>Uncertainty in supply due to yield variability</u>

This variability is present at two levels

(a) purchased parts and

(b) intermediate items

(a) <u>Purchased parts</u>

An MRP explosion tells us exactly how many units of the purchased item are needed in a period. Thus, the explosion might indicate that we need 127 units of item X. Does this mean that we can place an order for exactly 127 units? No! This is because the quantity we receive may be within 10% or so of the quantity ordered. This will be specially true of low cost high volume items.

Lot sizing will help to reduce this risk but does not eliminate it. One way of taking care of the problem is to order net requirements + a safety factor. This safety factor may be 5% or 10% of net requirements depending on the variability experienced. For low volume items ordered in quantities of tens or twenties this problem does not arise. For high volume items we face the problem. If the items are low-cost high-volume then the additional cost is small. If the item involved is high-cost high-volume then we have to analyse the situation - it might be cheaper to reduce uncertainty at the suppliers end by some means such as keeping a representative there.

(b) Intermediate items

Yield uncertainty exists at intermediate levels due to scrap and productivity uncertainty. This will be particularly true at lower levels where machining is involved. Here again the uncertainty is reduced if the item is already being covered by some form of safety stock due to some other reason. This is because the probability of more than one safety stock causing factors occurrence is less than the probability of any one such occurrence since these are independent events.

This area is therefore highly situational dependent. If the yield variances are high enough then we should provide for safety stock by planning for a quantity equal to (net requirements*yield factor) where yield factor depends on the uncertainty. At any rate this will be a small amount of safety stock at mostly low level items.

Conclusions

We definitely need safety stock at the two interfaces to MRP viz. the end items and purchased items.

For end items we need safety stock to protect against forecast errors. Safety stock is based on the service level

and MAD.

For purchased parts we need safety stock to protect against variability in yield and lead time. Safety time takes care of lead time variation and increase in purchase order takes care of the yield problem.

For intermediate items the needs are highly situational dependent depending on -

- whether they are service items or not
- whether the work centre is running to capacity or not
- whether scrap and productivity problems are present or not

CHAPTER 5

LEAD TIME

Lead time at a work centre depends on the total load and the production rate. Lead time is directly proportional to total load and inversely proportional to the production rate. Given a production rate, as the load rises the lead time increases and this is mostly an increase in the queue time. Thus if the backlog becomes very large then the queue time can become a very substantial proportion of the lead time.

MRP assumes lead time to be constant regardless of the order quantity. Lead time is made up of two components - average queue time and processing time. If we have a good handle on lead times then the average queue time need not be a substantial fraction of the lead time unless the job arrivals at the work centres are very highly erratic. If the queue time is not a substantial fraction of the lead time then the second component - processing time - can materially affect the lead time. In such cases, lead time varies with the order quantity. A certain amount of this variability can be absorbed by

(1) working overtime

(2) moving people from less loaded work centres to more loaded work centres if people are the bottleneck.

However, both of these are not without cost. Overtime cost is direct and there is a cost of dislocation in moving people from one work centre to another. We have to ask ourselves the question - why do we need to assume fixed lead times?

If queue time is a very substantial fraction of lead time, then lead time is practically independant of the order quantity. As an example, if queue time is 90% of the lead time and if processing time increases by 50% due to a large order quantity, this means only a 50*0.1 i.e. 5% increase in lead time. However, a queue time so large means that either the job arrivals are very erratic or that the lead times are highly inflated. There is a heavy cost to the latter case in terms of larger in-process inventories.

In a well managed system, therefore, lead times cannot be assumed to be independent of the order quantities.

The question arises as to what should this planned lead time be? One point that should be kept in mind is that whatever number it be, it should be agreed on by everyone - management and the foreman. To get an idea of what the lead

time might be we have to ask the question "why do we want queues?" Management wants a queue to guard against fluctuations in the input rate. Foremen want queues because it makes them feel secure that they will not be idle - they will want a long queue. If the foreman sees the queue shrinking, he cuts the output and tries to preserve the queue!

In practice, lead times are often determined very arbitrarily. One firm that implemented an MRP system did not know where to begin in estimating lead time. It assumed a number on gut feel of x weeks. The system worked all right and so the lead time was reduced to (x-1) weeks. Again the shop ran smoothly and so lead time was reduced to (x-2) weeks. Now they ran into difficulties and so they established a planned lead time of (x-1) weeks!

Another problem that sometimes arises is that the lead time may not be an integral multiple of the bucket size. For a certain item, the lead time might be 1.5 weeks and the bucket size in use might be one week. In such cases, the lead time the system will use is two weeks. If this happens at a number of succesive stages then we are holding a lot of extra inprocess invantory. One way to get around this is to schedule by day rather than by week. Thus the schedule for an item would say we need so many items by this day and

offsetting by lead time we determine the day by which the next lower level item is desired. We use the shop scheduling calendar for this purpose<18>.

The way things happen at a work centre is that there is a random input and output. A queue is present to flex as the work arrival rate varies randomly. The queue has to be only long enough to act as a shock absorber to the random work arrival. So long as we do a good job on master scheduling, the queue varies in length but around a stable average. The lead time can be considered as being made up of three components -

Lead time = Queue time + Setup time + Process time

Cycle time

= Queue time + Setup time +

(process time per unit)*(lot size)

The queue time component is precisely the stable average we were talking about above. This is an estimate. We have to manage the queue to this average. The other two components of the lead time are deterministic.

If we use lead times as calculated above as the planned lead times and observe the jobs going through a work centre then if 50% of the jobs go through faster and 50% of the jobs go through slower than planned (due to queue

conditions) then we know that the average queue time is being maintained. This is not something to get upset about. This is because a job goes from one queue into another queue. At each queue, jobs are sorted in line based on the relative priority in the queue. Jobs that are ahead are pushed back and jobs that are behind are pushed ahead. We are therefore in the constant recovery mode and queues provide the opportunity to catch up - in effect acting as a safety factor in themselves (so long as the queues are managed!). Thus if jobs go through 15 work centres then we are recovering 15 times back to the original schedule.

Real problems occur when there is an average input to average output unbalance. Then the queues will either build up or dry up. In order to prevent such occurrences we have to monitor the work centres using I/O controls<66>. If the queue grows then we have to use overtime or some other means to manage it. One reason why such unfortunate things might happen is that the average queue time estimates were awry to start with. Another reason might be poor master scheduling leading to unbalanced work centres, in which case an average queue time is not meaningful.

In conclusion, it is suggested that lead times be calculated as a sum of average queue time, setup time and processing time. To do this, the average queue time has to

be computed. This can be achieved by studying the length of the queue with time at each work centre. Once this is done, I/O control<66> has to be maintained at each work centre to spot average input to average output mismatches. If the system is to succeed then another function that has to be performed is job sequencing at queues by priority.

CHAPTER 6

LOT-SIZING

MRP literature does not discuss master scheduling except to say that it should not be overstated. If we do a good job on master scheduling somehow then this means that the shop will work to capacity as will the work centres. If we now explode the master schedule using MRP, arrive at net requirements and lot-size then we are effectively meddling with the master schedule because previously balanced work centre loads are upset. This problem will not arise only if master scheduling took into account lot-sizing and we are using the computed lot-sizes. Lot-sizing can be of saving wherever setup costs are high. Hence the need to lot-size exists.

All of these arguments point to the need for taking into account lot-sizing effects on shop floor loading at the level of master schedule itself.

Keeping this in mind, there is not much point in discussing the merits and demerits of the individual lot-sizing techniques such as Least Unit Cost, Least Total Cost, Part Period Balancing, Period Order Quantity, Fixed Order Quantity, etc. Descriptions of these techniques can be

found in Orlicky<45>. Another problem with these techniques is that they are all single stage techniques. Thus, benefits gained due to lot-sizing at one level may be more than offset by the impact this has on the lower levels.

To illustrate, consider the requirements schedule shown in Figure 13 (a reproduction of Figure 61 in Orlicky<45>). The figure shows the lot-sizes for the Least Total Cost technique. The values for the pertinent parameters are:

Setup cost S = \$100

Unit cost C = \$50

Carrying Cost I = \$0.24 per annum

Ip = \$0.02 per period

Suppose this item creates gross requirements onto its lower level item which has the following characteristics:

Setup cost S = \$10

Unit cost C =\$40

Carrying cost I = \$0.24 per annum

= \$0.02 per period

Economic Part Period (EPP) = S/(Ip*C) = 13

If we still use Least Total Cost, then for the next level the planned-order coverage will be as shown in Figure 14. For this lot-sizing, the inventory cost will be:

Period	1	2	3	4	5	6	7	8	9	Total
Net requirements	35	10		40		20	5	10	30	150
Planned-order coverage	85					65				150

Figure 13 Least total cost.

Period	1	2	3	4	5	6	7	8	9
Net requirements	35	10		40		20	5	10	30
Planned-order coverage	85					65			

Period	1	2	3	4	5	6	7	8	9
Net requirements	85					65			
Planned-order coverage	85					65			

Figure 14 Least total cost at two levels.

Setup costs = $(2*10) = $20

Carrying costs = $(40*0.02)(10+120) + (40*0.02)(5+20+90)

= $196

Hence, Total Inventory Cost = $(20+196) = $216

Suppose, however, that lot for lot was used at the parent level and the lower level. Then the planned order coverage for the lower level item will be as in Figure 15. Now the inventory cost for the lower level item is:

Setup costs = $(7*10) = $70

Carrying costs = $0

Total Inventory Cost = $70

At the lower level, therefore, we would have saved $(216-70), i.e. $146. However, inventory costs for the higher level item would have been higher.

Thus lot-sizing techniques discussed in the MRP literature are single level techniques and inadequate anyway.

MRP literature also says that safety stock where required should be kept at the end item level. This is because if any uncertainty exists, it is at the master production schedule level and not at the component item level. Literature adds that in an MRP system, demand for

Period	1	2	3	4	5	6	7	8	9
Net requirements	35	10		40		20	5	10	30
Planned-order coverage	35	10		40		20	5	10	30

Period	1	2	3	4	5	6	7	8	9
Net requirements	35	10		40		20	5	10	30
Planned-order coverage	35	10		40		20	5	10	30

Figure 15 Lot-for-lot at two levels.

the individual component items is not being forecast and is not therefore subject to forecast error.

Assuming this is true, the master production schedule will be frozen over the cumulative production lead time - any forecast errors for the end item are absorbed by safety stock at that level and there is no need to change the schedule.

However, when it comes to lot-sizing, MRP literature<45> turns right around and says that all discrete lot-sizing algorithms are based on the implicit assumption of certainty of demand, that in most cases the pattern of future demands is never certain and that therefore one lot-sizing algorithm is as good as another. Orlicky recommends lot for lot lot-sizing.

There is a clear contradiction here - it is a case of eating your cake and having it too!

Orlicky in his book<45>, page 169, says "probably the most serious problems that the inventory planner must cope with are discrepancies or misalignments between net requirements and coverage, resulting from unplanned events or increases in gross requirements."

In the first place, this should not happen in MRP

because demand for component items is certain and uncertainties are tackled at the end item level. Assuming that it happens, however, the problem and its solution presented in MRP litarature is as below:

Suppose the inventory record for item A is as shown in Figure 16. Now suppose that the gross requirements in period 4 go up to 30 because of an increase in the planned order release of its parent item. The situation will then look as in Figure 17.

Now notice that there is a net requirement for 10 units of item A in period 4. However, since the lead time is 4 periods, this requirement cannot be satisfied even if a planned order is immediately released. Thus, either the processing for 10 units is expedited or some other solution has to be found.

At this point the user examines the inventory record for the parent of item A. He is helped in achieving this by means of the peg record. A peg record is a where-used record that allows us the capability to trace the source of item demand to the immediately higher level. The user notes that the gross requirement of 30 units of A in period 4 is needed to cover the net requirement of 9 and 21 in periods 6 and 7 of its parent item. Hence one solution is to change the lot

Item A

Lead time = 4 periods

		1	2	3	4	5	6	7	8
Gross requirements		32			20		10		
Scheduled receipts				12					
On hand	40	8	8	20			-10	-10	-10
Net requirements							10		
Planned-order releases			10						

Figure 16 Status of item A.

Parent of Item A

– Lead time = 2 periods

		1	2	3	4	5	6	7	8
Gross requirements		10	15	20	5	7	9	21	10
Scheduled receipts									
On hand	25	15	0	-20	-25	-32	-41	-62	-72
Net requirements				20	5	7	9	21	10
Planned-order releases		32			30		10		

Item A

		1	2	3	4	5	6	7	8
Gross requirements		32			30		10		
Scheduled receipts				12					
On hand	40	8	8	20	-10	-10	-20	-20	-20
Net requirements					10		10		
Planned-order releases		10	10						

Figure 17 A coverage problem for item A.

sizes of the parent item to 9 in period 4 and 31 in period 5. The result is as shown in Figure 18.

Note, however, that this is possible only because of the lot-sizing used. If lot for lot lot-sizing is used then the above would not have been possible!

In conclusion, MRP literature is inconsistent on the point of lot-sizing. All techniques discussed in MRP literature are single level techniques anyway. In order not to meddle with a good master schedule and yet do lot-sizing where large setups are involved it is suggested that lot-sizing considerations be made at the master schedule level.

Parent of Item A

		1	2	3	4	5	6	7	8	
Gross requirements		10	15	20	5	7	9	21	10	
Scheduled receipts										
On hand	25	15	0	-20	-25	-32	-41	-62	-72	
Net requirements				20	5	7	9	21	10	
Planned-order releases		32			9	31				

Gross requirements		32			9	31				
Scheduled receipts				12						
On hand	40	8	8	20	11	-20	-20	-20	-20	
Net requirements						20				
Planned-order releases		20								

Figure 18 Coverage problem resolved.

CHAPTER 7

MRP EVERYTHING

An important issue is whether item should be controlled using MRP or not. Most firms, for example, control items such as nuts, bolts, cotter pins etc. by a two bin system or some form of reorder point system. Some questions that need to be answered are-

- should all items be put onto the bill of material?
- should all items be controlled by MRP?
- if not, then which items are candidates for some alternate form of control?

The first two questions above are actually inter-related - if we want to control an item by MRP it has to be on the Bill of Material though the reverse is not true.

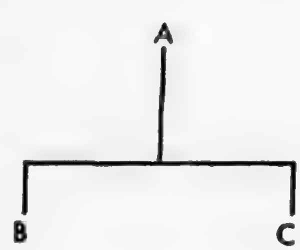
In many cases, the Bill of Material is also a manufacturing or shop floor document. In such cases clearly every single item has to be on tha bill.

Often times a company may decide to leave a few items out for some reason or other. Most commonly these reasons relate to cost, usage and lead time. These paremeters are

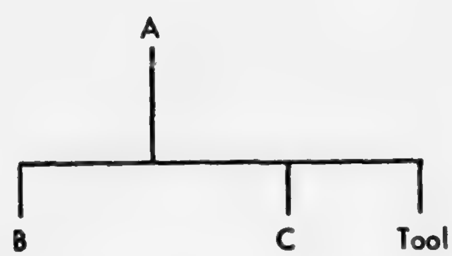
not constant, however, and can change very substantially. Lead times, for example, can vary widely depending on industry specific circumstances or on the state of the economy. With these fluctuations an item that the firm decided was not worthwhile to put on the Bill of Material may suddenly become important and the firm may want it on the bill- or worse, the firm may not realise that it needs the item on the bill under changed circumstances and this may result in a stockout! This is another reason why firms may want all items on the Bill of Material.

Some firms do not put all items in the bill because they believe the cost of doing so exceeds the benefits. As Leroy Peterson<50> says, "In one case, the savings in the computer disk storage capacity which resulted from elimination of common hardware on the bills of material was approximately 40% of what was estimated for a complete bill of material file".

Very often the firms extend the Bill of Material rather than cut it down. For example, suppose we have part of a product structure as below.



Making of subassembly C, however, needs a machining operation requiring the use of a tool. Depending on the quantity of item C to be made, we may need 1 or more tools. We can make MRP tell us this by adding the tool onto the Bill of Material and building in the proper logic into the software.



Sometimes the firm may decide to implement support functions which will access the Bill of Material file. One such function that readily comes to mind is cost accounting by unit or by batch. Then again it is essential that all items be on the Bill of Material.

From these points it seems to be clear that there are number of benefits to be gained from having all the items on the Bill of Material. The only saving that arises is the

disk space. In only rare situations, I think, will this saving outweigh the benefits. Moreover, disk storage is getting cheaper with time.

Let us examine all items along the dimensions which are most important in determining whether they should be controlled by MRP or not- unit cost, lead time and usage. Different combinations of these are shown in Figure 19.

There are two situations under which we might not want to control an item under MRP.

(1) It might be impossible to maintain accurate inventory records on some items. Typical items that fit this situation are nuts, bolts, wire, flux, carbon resistors etc. MRP is of no use in controlling inventory if the inventory status is highly suspect- in fact use of MRP under such circumstances will lead to an unexpected stockout 50% of the time. This is so because 50% of the time we will have more on hand than the records indicate and 50% of the time we will have less- and MRP places a planned order only when projected inventory becomes negative. Such items should be controlled using reorder point. Typically these items are low-cost high-usage items, usually having a short lead time. To make sure that we do not hit a stockout situation for such an item, a large safety stock is maintained.

	Unit Cost		Lead Time		Usage		MRP?
	Expensive	Inexpensive	Long	Short	High	Low	
1	✓		✓		✓		✓
2	✓		✓			✓	✓
3	✓			✓	✓		✓
4	✓			✓		✓	✓
5		✓	✓		✓		×
6		✓	✓			✓	×
7		✓		✓	✓		×
8		✓		✓		✓	✓

Figure 19 MRP everything decision table.

Sometimes it is argued that the demand for such items might be highly variable or peaked and so even reorder point with large safety stock will result in stockout. However, demand can be peaked or variable only in comparison to the order quantity and safety stock. If the order quantity and safety stock are large numbers in comparison to the requirements then the relative variability is highly reduced.

(2) Consider a product with the lead time relationship shown in Figure 20.

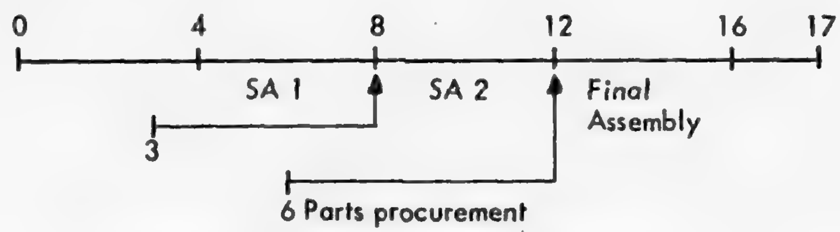


Figure 20 Product lead time relationship

This shows us that in order to finish a unit of the end item in week 17, we need to order parts in week 0 for subassembly 1, parts in week 3 for subassembly 2 and in week 6 for the final assembly. The figure also shows the start and finish weeks for each stage.

Now suppose, however, that we need a casting to be purchased for subassembly 2 and that this casting has a lead time of 20 weeks even though it is an inexpensive item. The lead time relationships then look as in Figure 21.

Now thw parts for subassembly 2 should have been ordered in week -12. The cumulative lead time has gone up by 12 weeks just because of the casting. This means we would need to forecast further into the future and need to freeze over a longer horizon- both of which we would not like to do.

It seems clear that we would rather not control long lead time inexpensive items using MRP. Again we would use reorder point with a large safety stock.

It must be pointed out that we would still like to retain the item on the Bill of Material and explode the time requirements. This time requirement information is very useful. Besides, this information is used for issuing material to the shop floor.

Combinations 5 and 6 of Figure 19 are hence not MRP controlled because of the above problem. Combination 7 is not MRP controlled because of stock status inaccuracy. Combination 8 has none of these problems and can be MRP controlled.

In conclusion, therefore, the critical factor seems to become the unit cost of the item. All expensive items should be MRP controlled to keep inventory level low and service level high. Inexpensive items should not be MRP controlled.

All items should be exploded to generate time requirements information. For the inexpensive items, though, this information is used for (1) issuing material to the shop floor rather than for inventory control and (2) to be forewarned of any unusually large requirements.

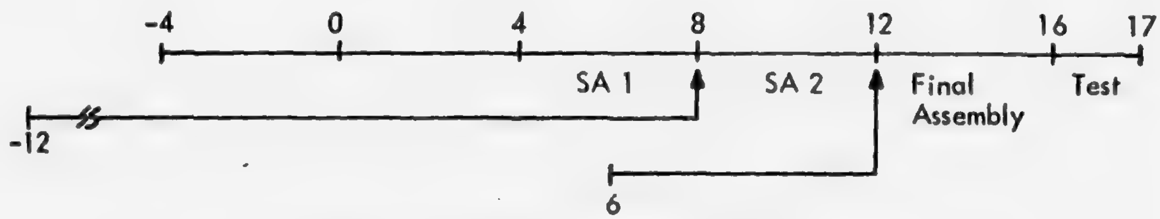


Figure 21 Modified product lead time relationship

CHAPTER 8

INDUSTRY SURVEY

As part of tha research effort to get a feel for what real life implementations were like we decided to conduct a survey. A total of seven firms were personally visited and discussion usually took place with two or three people including the Materials or Manufacturing Manager and the Systems Analyst incharge of the MRP project. Each of these firms was asked nearly 40 questions though not necessarily in the same order. The order depended on the flow of conversation. In many instances answers to questions were less than satisfactory or not available and further probing only led to a change of topic. The questions posed can be grouped under the following subheadings -

- general, overall
- master scheduling
- frozen master schedule
- safety stock
- lead time
- MRP everything
- lot sizing
- nervousness
- system parameters, capabilities

Rather than give the answers to the questions by each firm, the following strategy will be adopted. A brief description of each firm will be given at the start. We will then proceed to list different responses under questions in each subheading. We will follow this procedure because this is not an attempt to study the MRP implementations of different firms but to see what different firms do to tackle the issues discussed in the previous chapters.

Company A

This company is in the business of producing instruments and systems for process management and control. The corporation as a whole produces over a thousand different products world-wide and has salas in excess of $300 million (1975). We studied the MRP implementation at one of their plants which makes electronic process control instruments mostly. The plant has 20,000 item numbers and the bills of material are 2 to 6 levels deep. The end products come in many different models of common functioral units. The firm makes to order and has about 1.5 years experience with MRP.

Company B

This company is in the business of designing, manufacturing, selling and servicing computers, peripheral

and computer accessory equipment and other systems using digital techniques. The company has manufacturing facilities world-wide and has sales in excess of $500 million (1975). The plant studied has 50,000 part numbers and the bills of material are upto 10 levels deep. The company is in the process of installing an MRP system and the systems work has been completed. Systems are currently being tested and run in parallel with the existing system.

Company C

This company is in the business of designing and producing gas ignition and temperature control equipment. The company's manufacturing facilities are centrally located and sales are in excess of $30 million (1975). The company has 17,000 item numbers and the bills of material are 6 levels deep. The firm has almost 4 years MRP experience.

Company D

This company designs and produces products such as mechanical and diffusion pumps, accessories and components, vacuum gauges and gauge controls, leak detectors etc. The company has sales in excess of $10 million (1975). The firm makes to stock and has 15,000 part numbers and the bills of material are upto 9 levels deep. The company had an MRP like system for 10 years. It is now in the process of switching

over to MRP as it is known today. The new system is not up and running as yet.

Company E

This company is in the business of design and production of microwave components primarily used as building blocks for radar, missile and telecommunications equipment. The company has sales in excess of $50 million (1975). The plant has 40,000 part numbers and the bill of material is upto 11 levels deep. The company has almost 2 years of experience with MRP. This company was very evasive in its answers and did not answer a number of questions.

Company F

This company designs, manufactures and markets electronic components and subsystems used for the acquisition, conditioning, conversion, transmission and display of digital and analog data in precision measurement and control systems. The firm makes more than 300 products, has 5000 parts and has sales in excess of $30 million (1975). The firm has a single level bill of material. It is engaged only in assembly operation and has no manufacturing. The firm ran an explosion 4.5 years abo and is pursuing MRP vigorously.

Company G

This firm designs, manufactures and markets medical electronic measuring devices and monitoring equipment such as central station monitoring equipment, intensive care units, pacemakers, cardiovascular instruments etc. The company has sales of near $80 million. It has 40,000 part numbers and the bills of material are upto 8 levels deep. The company makes systems mostly to order and is in the process of switching over from an MRP like system to MRP.

We now present the results of the questionnaire.

General,Overall

Q1. What first brought you onto the idea that MRP would be beneficial to your firm?

Q2. From where did the suggestion for MRP first come? From management? From sales? From production?

Of the 7 companies, 4 companies were put onto MRP by the suggestions of consultants. 2 firms had MRP like systems runnung and to tham this was evolutionary. One firm considered MRP seriously through the readings of the Manufacturing Manager.

Q3. Before MRP what system did you have? What problems did you run into using that system that made you think of

an alternate system?

Before MRP, 3 firms had reorder point systems and 2 firms had MRP like systems. At 2 firms we could not find out because the people we spoke to had not been there long enough.

The firms that used reorder point previously cited the following as problems they had

- reacted too late
- master scheduling problems
- inventory was out of phase with production
- big backlogs
- low service levels to customers
- inventories were inaccurate
- pyramiding stocks

Q4. Was an economic justification made before the decision to install the MRP system? Was it a formal analysis? If yes, who conducted the analysis? If no, did you go by gut feel alone?

Of the 7 firms, 6 firms made no economic justification or analysis before embarking on MRP. They cited reasons such as - "we felt we could not do without the system" or "we felt we needed the system". One firm that is now in the process of switching over fron an MRP like system to MRP

said that a Return on Investment calculation had been made - no figures were given.

Q5. What benefits did you expect in using MRP? Have you achieved the benefits? Give figures and statistics.

The following were mentioned as expected benefits from using MRP-

- better service level
- reduction in inventory
- better time information
- shorter lead times
- easier job release
- priority maintainance

No firm mentioned all of the above and at most 3 of the above benefits were cited by any one firm. All firms agreed, however, that the benefits they had expected had been realised. Not a single firm could come up with figures of the benefits achieved- they were going on feel.

Firm A cited the following as unexpected benefits achieved-

- change of attitude - "we think of the future now instead of the past".
- found out how poor the inventory data base was
- found out how poor their bill of material was

Firm C said that an unexpected benefit was that they had discovered obsolete inventory.

Firm E said that the rescheduling capability was an unexpected benefit.

Q6. Is the system IBM PICS, modified PICS or custom designed? Did you look at alternate systems?

The Firm A system is IBM PICS with modifications. These modifications were carried out by IBM people.

The Firm B system has been developed totally internally.

The Firm C system is IBM PICS off the shelf and without any modifications.

Firm D has purchased DBOMP (Data Base Organisation and Maintainance Processor) and RPS (Requirements Planning System) from IBM. The rest of the system has been internally written.

Firm E has done the same as Firm D.

Firm F has customised DBOMP and RPS and has programmed the printing of a number of other reports using the MRP data bases.

Firm G purchased BOMP and did the rest of the systems work themselves, modelling after PICS.

Q7. What was the estimated total cost of implementing the system? In terms of equipment? In terms of man-hours?

Firm A has been using an average of 5 people per year full time since 1971-72. Could give no dollar estimates.

Firm B estimated the cost to be $100,000.

Firm C used about 2 man-years of internal effort and paid $16,000 in consulting fee.

Firm D had no idea of the costs whatsoever.

Firm E estimated 16 man years of effort into systems work.

Firm F had no idea of the cost of the system.

Firm G had no idea either but hazarded an estimate of roughly 3 man-years plus involvement and time of all kinds of other people.

Q8. How much time did the installation take?

It took Firm A 4 years and they are still working on it.

Firm B took 1 year to design the system.

Firm C took 3 years but they stressed that they hired no extra people- existing staff was used.

Firm D has given the project low priority due to funds and it is still tridging on.

For Firm E the implementation time was nearly 2 years.

Firm F took 2 years.

Firm G took 1.5 years.

Q9. What data processing equipment do you have to support MRP? Did you already have it or did you acquire it for MRP?

Firm A switched over from an IBM 360 to an IBM 370. However, they said they would have done this anyway.

Firm B runs the system on a DEC-10.

Firm C switched from an IBM 360 to an IBM 370 because of MRP.

Firm D is not yet running MRP. Their MRP like system is runnung on an IBM 360/40 in an IBM 1440 emulation mode.

Firm E also switched from an IBM 360 to an IBM 370 but

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said they would have done this anyway.

Firm F runs MRP on an IBM 370 and acquired this for general and future use, and not just for MRP.

Firm G runs their MRP like system on an IBM 360/30. The new MRP system will run on HP machine.

Q10. Do you have other computerised information systems?

All the firms had a number of computer based management information systems. The commonly mentioned ones were Receivables, Payroll, Sales Analysis etc.

Q11. What did you first install- aggregate capacity planning, shop floor control or MRP?

Firm A first had a manual capacity planning system. It then installed MRP. It does not as yet have a Shop Floor Control System.

Firm B has no aggregate capacity planning. They have only just finished the MRP system and some form of I/O control will soon be finished.

Firm C has no capacity planning. They went from MRP to Shop Floor Control (very recently installed) in that order.

Firm D has no capacity planning. It has Shop Floor

Control but the MRP system is not yet up.

Firm E has MRP only.

Firm F has MRP. They plan to have capacity planning and shop floor control in that order.

Firm G plans to proceed as MRP- manual capacity planning- shop floor control.

Q12. In the MRP design, were the users actively involved or was it mostly the work of consultants?

All firms said that the users were actively involved in the design of the MRP system.

Q13. Have you had any serious problems after or during the implementation of the MRP system?

The following MRP related problems were cited by the firms.

- better shop floor control has to be maintained
- stockroom control has to be much tighter. (Almost always padlocks were used and the stockroom was controlled with military precision).
- getting oriented to the system takes a long time for people. There is a lot of user resistance.
- lot of maintainance involved

- creation and maintainance of lead times were a problem
- master scheduling was a problem

Master Scheduling

Q14. How is your master schedule prepared? What is the exact proceaure? How do you ensure that shop loading is satisfactory? Do you use MRP as a 'simulation' and go back to change the master schedule?

Firm A

This firm divides its end items into 'rate groups' based on manufacturing specification.

A master production plan is first prepared. This is a capacity plan and is done monthly. Maximums are set for each rate group though the mix within a rate group can vary. The production plan consists of production schedules for each product within the rate groups based on mix of forecast demand.

Within 5 weeks the master schedule is composed of only firm orders from customers. Outside 5 weeks the master schedule is the forecast or sales orders, whichever is larger, so long as the sum within a rate group does not exceed the maximum. The firm quotes delivery times of 12 to

18 weeks, has a cumulative lead time of approximately 28 weeks of which 3 weeks is the final assembly lead time.

The firm does not have shop loading profiles printed as yet but plans to implement such a system. Work centres work overtime and they use subcontracting to take up unbalanced loads.

Jobs through the shop are tracked manually and a weekly I/O report is prepared manually.

Firm 8

This firm does not do any aggregate capacity planning. They use forecasts, history, economic trends and other indicators to come up with sales targets which is then translated into a production schedule. They feel that they can derive and meet sales targets very accurately. They also feel that they do a good job on long range capacity planning and stay ahead on capacity. (From talking to other people in the firm, however, I got the impression that this was not true. The firm was growing so fast that they were selling whatever they could make and so were effectively behind capacity). Sales targets are set by top management together with marketing and production. The firm does not have shop loading profiles as yet but plans to do work centre balancing using MRP outputs in the future. They have I/O

control.

Firm C

This firm could not come up with a formal master scheduling procedure description. They used backlog and forecasts to prepare the master schedule. At the back of their minds they hava an estimate of their capacity in terms of man-hours and they do not schedule more than capacity.

They do not have any shop floor control. They know that shop loading is not uniform and use overtime and safety stock to take up unbalanced loads.

The firm does not generate shop loading profiles.

Firm D

This firm has "planning meetings" every 4 to 6 weeks. Their products are divided into product groups or families based on sales groups. e.g. all vacuum pumps would be one product group even though their setups and routings may be widely different. For each product group there is a product manager. The product manager, product planner and production control manager meet. They review the usage of all stocked items for the past 2 periods, review backlog reports, pool together any negotiations they are making for sales, consider external economic factors and trends and come up

with a production schedule. They have informal capacity estimates at the back of their minds in deriving the master schedule.

The firm has shop floor control but shop loading profiles are based only on released jobs.

Firm E

The master schedule for this firm is derived as (forecast sales/12) per month. No formal capacity considerations are made. Some form of informal and intuitive maximum was at the back of the mind of the schedulers. Sales for the firm were not cyclical but steadily rising. No shop loading profiles existed. Loading problems existed at work centres and particularly in the machine shop which was common to the different product lines. The firm has no shop floor control.

This firm was particularly guarded and evasive in its replies and unwilling to provide satisfactory answers.

Firm F

In this firm, master scheduling is still run by the marketing people and not by the production people. They said that master scheduling was their biggest problem. Forecasting was done at the end item level even though

different models of an end product existed. Based on these forecasts, marketing came up with a production schedule which manufacturing tried to meet. The manufacturing people were trying to change this so that production may meet schedules. Shop loading profiles are generated as bar charts and I/O control has been designed.

Firm G

At this firm the master schedule is-(backlog+orders+forecast)/12 after this figure has been reviewed by the scheduler. The master scheduling is done on the basis of dollars and not units or man-hours. The business is not cyclical though peaks exist.

Work centre balancing is not considered. The firm is not running MRP as yet and plans to have manual capacity planning and also a shop floor control system.

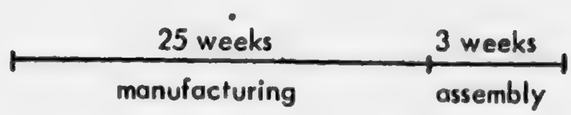
Frozen Master Schedule

Q15. Do you allow changes in the master schedule within the cumulative lead time? Is the shop running to capacity?

Q16. What makes you feel you can change the master production schedule within the cumulative lead time? Do you change timing or quantity or both? Are lower level assemblies of common usage?

Firm A

The lead time configuration for this firm looks as below.



The firm has a 5 week frozen schedule and this is based on firm orders. Beyond 5 weeks they allow variations in both quantity and timing. Whether they run to capacity or not depends on which part of the cycle they are at.

They allow changes within the cumulative lead time and still meet schedules (delivery lead times are 10 to 15 weeks) because of the following flexibilities.

- capacity can be easily changed by moving people from one work centre to another, working overtime or extra shifts and subcontracting.
- use compensating changes - if one quantity is increased another quantity is reduced.
- they forecast optimistically and hence reductions will normally result
- they change delivery times

- keep safety stocks at certain levels

Firm B

The manufacturing activity in this firm is divided into two parts as below.

Final Assembly and Testing

Volume Production

The volume production facility manufactures the basic building blocks (level 1 items in a modular bill of material). Final assembly and testing assembles the final product to customer specification. Final assembly and testing provides a master schedule to volume production based on what it thinks it needs and this schedule is firm. Forecasting and safety stocking at the level 1 items is hence the problem of final assembly and testing. Volume production uses MRP to explode the requirements. Hence the production schedule is firm. This is true of the one plant they are pilot testing MRP on. They plan to use MRP at other plants too where this may not be true. At these plants they plan to allow changes within the cumulative lead time because

- many lower level items are common items

- they have capacity flexibility viz. work centres work overtime or additional shifts as needed and also people can be moved from one work centre to another.
- keep safety stock at the raw material level
- queue times are a large fraction of lead times.

Firm C

The lead time picture for this firm is

The firm does not like changes within 15 weeks but allows changes in the last 5 weeks of cumulative lead time. They say they are running to capacity- "people are kept busy- we release enough to the floor". The firm maintains safety stocks of 2 to 6 weeks at every level. Demand is steady and not seasonal. There are a number of common usage items and overtime is used as needed.

Firm D

This firm quotes delivery times of 2 weeks and has a cumulative lead time of 20 weeks. The firm makes to stock, forecasting is not very good and jobs get delayed along the

line. The production schedule is frozen for 8 weeks. As far as possible they do not like to change within the cumulative lead time. If change is necessary it is done manually after evaluating the position of critical parts. If necessary they move another item out to compensate for the change. The flexibilities they have are

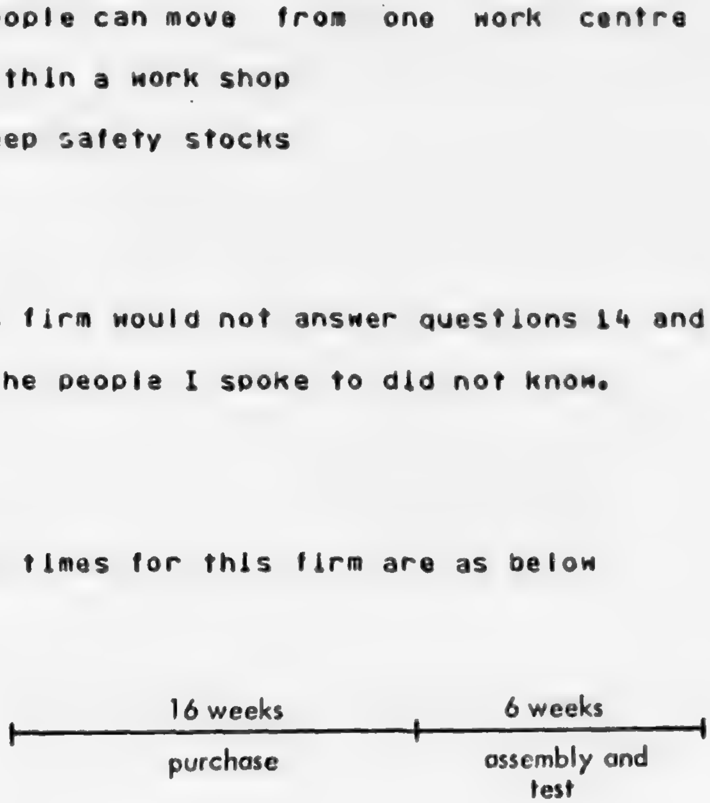
- overtime is used extensively
- people can move from one work centre to another within a work shop
- keep safety stocks

Firm E

This firm would not answer questions 14 and 15 probably because the people I spoke to did not know.

Firm F

Lead times for this firm are as below



The firm quotes a maximum of 8 weeks delivery time and the master schedule is almost frozen for 8 weeks (they allow changes within 10%). Beyond 8 weeks changes are allowed.

The firm has a backlog of approximately 6 weeks. Variations in the master schedule are permissible because they maintain 5 to 6 weeks of safety stocks for purchased material and work overtime as needed. We have to keep in mind that they have a single level bill of material.

Firm G

This firm has a cumulative lead time of 24 weeks. They allow changes within 24 weeks though timing changes are preferred to quantity changes. Any changes within 17 weeks which require more than 3 weeks of pull-in requires approval. Tha firm is able to do this because

- they use lots of overtime
- they move people from one work centre to another within a shop
- they can expedite vendor deliveries.
- Safety Stock

Q17. For the end item, how do you compute safety stock?

Q18. For purchased parts, how do you compute safety stock?

Q19. For service items, how do you compute safety stock?

Q20. For intermediate items, do you use safety stock or not? If yes, why do you keep safety stocks? Is the safety stock in terms of safety time, fixed quantity or some other technique? How do you compute the amount of

safety stock?

Firm A

No safety stoch is maintained at the end product level because they make to order only.

Safety stock is maintained at purchased part level. This safety stock is based on a MAD*S.L. (Mean Absolute Deviation*Service level) calculation where the service level varies depending on the A,B,C classification. Almost 30% of purchased items are safety stock.

Service items are low level items which are safety stocked.

They carry safety stocks at intermediate levels 4 and 5 and some other levels depending on the experience and feel of the planner. The planner also often determines the amount of safety stock.

Firm B

For level 1 items, final assembly and testing keeps safety stocks based on experience.

For purchased parts, safety stock is based on classification.

A items - 2 to 4 weeks of safety stock

B items - 4 to 6 weeks of safety stock

C items - 8 weeks or so of safety stock

Safety times are also used depending on the planner.

Service items is again the problem of final assembly and testing and they keep safety stock based on experience.

For intermediate items they feel they have safety stock built in because when sales are rising they schedule more than requirements and when sales are falling they use out of stock and replenish stock.

Firm C

This firm keeps safety stock for end items based on reorder point principles viz. MAD*S.L. calculation.

For purchased parts they keep 1 months supply as safety stock and have 1 week of safety time.

Service items have low demand and no extra stock is maintained for them.

A safety stock of 2 to 6 weeks is used at all intermediate levels.

Firm D

For items made to stock, safety stock is kept. The amount of safety stock depends on the feel of the product manager which is based on the sales rate (and not forecast error since they do no know how much they have sold) and an A,B,C cllassification.

For purchased parts, safety time is used.

For service items safety stock is determined on feel.

For intermediate items, safety stock is maintained for some items and not for others. This is based on historical experience depending on which parts have given trouble in the past.

Firm E

For end items no safety stock is maintained as these are built to order. A yield factor is incorporated at this level.

For purchased items, safety stock and 1 week of safety time is used. Would not say how much safety stock was kept. For one purchased part- castings- which had 30 weeks lead time and was also expensive, 1 years supply was stocked.

No answer was available as to safety stocks for service level items and intermediate levels.

Firm F

No safety stock at the end item level because they make to order.

For purchased parts, they purchase more than needed so that a rolling safety stock is available.

Service items are not an important consideration.

For intermediate items, a yield factor was used.

Also,safety stock was maintaineo based on experience.

Firm G

For end items, no safety stock is kept. They run overtime when mora production is needed.

For purchased parts, they kept stock where needed. In a sellers market they kept safety stock and when it was a buyers market they did not keep safety stock. Did not know how safety stock was computed.

Service item safety stock is taken care of by the distribution centre. The distribution centre places orders upon manufacturing.

For intermediate items no safety stock was kept. Overtime was used as needed.

Leao Time

Q21. How do you determine lead times for purchased items and produced items? What is your cumulative lead time? Do you control lead times? Do you have I/O control? What percent of lead time is queue time? Do you vary capacity by working overtime or moving people from one work centre to another?

Firm A

For purchased items, the lead time is taken as the vendors estimate.

For assembly operations, the process engineer provides an estimate.

The firm estimated that 70% of lead time was queue time. No studies of queues had been made to determine internal lead times and no vendor ratings were used for suppliers.The firm has some form of a weekly manual I/O control to keep a handle on lead times.

Firm B

For purchased parts the vendor estimates are used as lead time. An informal vendor rating is used by the planner and he keeps safety time if necessary.

For internal lead times, the figures provided by the floor are used. They feel these lead times are inflated but have performed no study to estimate what a good lead time might be. They plan to have I/O control for lead times.

Firm C

Purchased part lead times are set by the planner. These are reviewed and updated "when necessary" though this has been done only oncu upto now.

Internal lead times are provided by the floor and are never updated. The firm has no I/O control and queue time is

60% of lead time. They are now looking to see if lead times can be shortened.

Firm D

This firm was having problems with purchasing lead times. Vendor quotes were not of much value as actual deliveries seemed to be randomly distributed about quoted delivery times. The purchasers used their judgement in arriving at lead times and safety time was used.

Internal lead times were provided by the floor and they felt that these were highly inflated. No I/O control is present. They plan to establish lead times on feel.

Firm E

Delivery times are vendor provided.

Internal lead times are the foremans estimates. They have no I/O control but said visual inspection of queues was done. No study has been made to estimate what a reasonable lead time might be.

Firm F

For purchased items, vendor estimates are used.

For internal assembly, a trial and error process was used. They started with a lead time of X and reduced this until they ran into problems. At this point they rounded the

lead time to the next higher level. To arrive at an initial estimate an average backlog and production rate were assumed. They estimated that queue time was 50% of lead time. They have I/O control for assembly and test shops on an aggregate level.

Firm G

For purchased items vendor estimates are used. There is no formal vendor rating- this is done informally by the planners.

For assembled items, the lead time is computed as

(cycle time*factor for run size+queue time)

The queue time is provided by the supervisor and production control jointly. They plan to have I/O control.

MRP Everything

Q22. Is every single item on the bill of material? If not, which items are left out? Why? Are all the items controlled by MRP? Which ones are not?

All firms had every single item on the bill of material. However, every firm controlled items such as nuts, bolts, 'expendables', 'class C items', etc using reorder point techniques.

Lot Sizing

Q23. Do you use lot sizing at all? If yes, at what levels and what techniques?

Q24. Why do you use the techniques being used?

Q25. Have you evaluated your lot-sizing techniques in retrospect? If so, what results do they show?

Q26. Do your lot sizes go over capacity at times? If so, how do you tackle the situation?

Firm A

For end items, lot for lot is used based on firm orders within each time bucket.

For subassemblies lot for lot is used or fixed period is used depending on the planner.

For purchased parts, Least Total Cost is used.

Lot sizing is not evaluated in retrospect and capacity constraints have not arisen.

Firm B

No formal lot sizing techniques exist. Lot sizing techniques used vary depending on the feel of the planner.

Firm C

At the end level, no lot sizing is used.

For purchased items, an A,B,C analysis is made and reorder point is used.

At intermediate levels, the planner determines the lot sizes by reviewing the requirements generated by the MRP explosion.

No retrospective analysis is carried out.

Firm D

At the final assembly level lot sizing is done by the people in the planning meeting. No formal technique is used.

At intermediate levels lot sizing is the responsibility of the planner in charge of the item and he determines the lot sizes on feel.

For purchased items again lot sizing is done by the planner.

Firm E

No answers were available to the questions.

Firm F

At the master schedule level lot sizing is done by the schedulers.

At intermediate levels, lot sizing was done on

feel.

For purchased parts no lot sizing was done. Minimums were used.

Firm G

At the master schedule level, fixed period lot sizing of 4 weeks is used.

At intermadiate levels and for purchased items, the lot sizing technique was fixed period where the length of the parlod depended on the class of the item.

Nervousness

Q27. Do you have a net-change or regenerative MRP system? (In a regenerative system, the entire master schedule is explodea on each run. In net-change only the changes in the master schedule between runs are exploded).

Q28. If it is a net-change system, then do you ever regenerate? If so when and why?

Q29. If net-change, how do you take care of frequent changes?

Q30. How frequently is the net-change or the regen run?

Questions 28 and 29 turned out to be redundant because none of the firms interviewed had net-change MRP. The answers to questions 27,30,31,34,35,36 and 39

are best presented in the form of a table shown in Figure 22. (The questions follow).

Question 32 about non integral lead times also turned out to be of no relevance because lead times were so grossly determined that they were always assumed to be in weeks.

System Parameters, Capabilities

Q31. What is the size of the time bucket?

Q32. What if the lead time is non integral of the time bucket size

Q33. Why did you choose the time bucket size you have?

Q34. What is the length of the planning horizon?

Q35. Does the system have pegging capability?

Q36. Does the system have the firm planned order capability?

Q37. What are some of the outputs generated?

Q38. Can you track the progress of a particular job?

Q39. How many hours does a typical computer run take?

Q40. What are the improvements you would like to see in your system? What are your plans for the future?

Q41. If you were to start all over again, what would you do different?

In reply to Question 33, only 2 firms said that they felt 1 week was natural for the time bucket size. All others

	Net Change or Regenerative	Frequency weeks	Size of Bucket in weeks	Planning Horizon in weeks	Pegging Capability?	Firm Order Capability	Computer time per run (hours)	Type of Computer
Firm A	Regen	1	1	78	Yes	Yes	8	IBM/370
Firm B	Regen	1	1	78	Yes	Yes	8	DEC-10
Firm C	Regen	1	1	30	No	No	8	IBM/370
Firm D	Regen	1	1	52	No	No	20	IBM/360
Firm E	Regen	1	1	50	No	No	-	IBM/370
Firm F	Regen	1	1	20	Yes	No	-	IBM/370
Firm G	Regen	4(1)	1	52	No	No	28	IBM/360

(1) This is the frequency of the MRP like old system. New system is not yet running

Figure 22 MRP survey system characteristics

chose 1 week as their bucket size because the consultant said so.

Sample outputs are provided in Appendix 1 in reply to Question 37.

Question 38 has been answered before.

Questions 40 and 44.

Some reactions to these questions were

- have to educate the users carefully
- would proceed slower - not so much sophistication so early
- would like more CRT displays
- are satisfied and envison no changes
- do good forecasting
- go to net-change
- install shop floor control

CHAPTER 9

OBSERVATIONS AND CONCLUSIONS

One very common practice observed in the electronic firms I visited was the practice of 'kitting'. For each end product, a kit list is available. This is also sometimes known as a 'pull deck'. This is nothing but a list of all items needed out of stock in order to make the end product. Kitting is the process of putting all such items needed to make the desired quantity of the desired end product into kits. These kits are prepared right at the start. Once these go onto the floor, they are 'staged'. This means that the items are taken out of the kits and sent to the work centres at which they will be needed. Some preliminary work might be done before the parts are sent to the work centres- such as bending and cutting resistor leads etc. Essentially, then, all the items have to be in stock before an order is released to the floor and in fact the parts are in queue at every work centre through which the job passes.

This is a historical procedure and was adopted so that a job is not stranded because 1 or 2 parts are not available. Such a situation used to occur because inventory records were bad. However, this is not quite the concept of

MRP. If the cumulative lead time is 20 weeks, it does not make much sense to kit a part that will only be needed in week 19! Continuation of this technique means higher inventory levels of parts, higher work in process inventory and longer queues.

Another universal practice was the tight control of the stockroom. This was controlled with military precision and people had to get used to the idea. All the stockrooms were caged in. Someone suggested that building stockroom cages might be a good business as MRP became more popular! Such control was maintained because data base accuracy was very important in MRP. All the stockroom records were within 1% accurate of cycle counts- and mostly they were within 1/2%. Despite such accuracy however, the kitting procedure is being used.

None of the firms was doing a good job on master scheduling. Aggregate capacity planning was absent and shop loads were uneven. However, all the firms had a lot of flexibility in terms of overtime, mobility of people, subcontracting etc. and this helped them achieve some kind of a balance.

No firm froze the master schedule over the entire cumulative lead time. Again, this was possible because of

the flexibilities discussed in the previous chapters.

Safety stock was maintained very definitely at the purchased parts level and at the end product (or level 1 product in the case of a modular bill of material) level. Safety time was built into purchased items due to informal lead time setting. Very often safety stocks were maintained at intermediate levels. Yield factors were built in. Safety stock quantities wera determined on feel.

Lead times were not analysed at all. These were taken as vendor lead times or shop floor estimates. Almost no effort was made at controlling lead times via I/O control and not a single firm had tried to study queues to determine reasonable lead times. As a result lead times were inflated and inthemselves provided a large safety factor. This being true, the assumption of fixed lead times regardless of quantity caused no problems.

Lot sizing was done almost entirely on the basis of feel and was done manually by the planners. No attempt was made to evaluate techniques in retrospect. Certainly no aggregate analysis was done.

All items were always included on the bill of material and all firms used reorder point for items such as nuts, bolts etc. Some firms did have cheap, long lead time,

purchased items which they still controlled by MRP.

Overall, I had the feeling that the firms had benefited even though they could not quantify their benefits. However, these benefits had resulted mostly due to better information provided by the MRP explosion rather than anything else. Most firms were complacent and were satisfied by the benefits they had achieved. From the study it was clear, however, that the firms were far from realising the full benefits achievable.

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MRP Related Cases

Clark Equipment Construction Machinery Division, ICH 1-676-052

Corning Glass Works Erwin Automotive Plant, ICH 9-675-152

Granger Transmission (A), ICH 9-675-201

Granger Transmission (B), ICH 9-675-202

Granger Transmission (C), ICH 9-675-203

Markem Corporation (A), ICH 9-673-001

Markem Corporation (B), ICH 9-673-002

Pittsfield Manufacturing Company, ICH 9-613-068

APPENDIX 1

SAMPLE MRP OUTPUTS

Firm B

DATE RUN 16-MAR-76
CURRENT WEEK 7603W1

MATERIAL REQUIREMENTS PLANNING

*** JOB PRIORITY REPORT ***

WIP LINE: 19

WINDOW: 34 WEEKS
DUE DATES: 7504W2 - 7611W3

* * * PAST DUE * * *

PART NUMBER	---JOB NUMBER---	PART TYPE	DESCRIPTION	------DATES------ RELEASE	DUE	TOTAL STD COST	TOTAL STD HOURS	ORIGINAL QUANTITY	BALANCE QUANTITY
DH11-AA	M019-0DHAA-00939	OPT	PROCESSOR 16 LINE ASSYNC.	7504W2	7504W2	1275.6300	16.5000	1	1
DH11-AA	M019-0DHAA-01444	OPT	PROCESSOR 16 LINE ASSYNC.	7511W4	7511W4	1275.6300	16.5000	4	1
DH11-AA	M019-0DHAA-01459	OPT	PROCESSOR 16 LINE ASSYNC.	7511W4	7511W4	1275.6300	16.5000	8	1
CB11-DA	M019-0CBDA-01483	OPT	DISTRIBUTE MODULE	7512W1	7512W1	1037.7900	6.9000	3	3
DV11-HA	M019-0DVHA-01542	OPT	MOD SET & DIST PNL 8-LINE	7512W5	7512W5	1405.3000	16.0000	20	2
DU11-HB	M019-0LDHB-01578	OPT	PGM CHAP DET	7601W2	7602W2	1380.0000	40.0000	16	8
DV11-HA	M019-0DVBA-01593	OPT	MOD SET & DIST PNL 8-LINE	7601W3	7602W3	702.6500	8.0000	20	1
70-09711-01	M019-09711-01597	SUB	11/40-AC ASSY 115V-DC76	7601W3	7602W3	4030.2100	20.0000	3	1
DV11-AA	M019-0DVAA-01606	OPT	SYNCH MUX CONT UNIT 9-SLOT	7601W4	7602W4	6541.3000	115.0000	10	5
DV11-HA	M019-0DVHA-01607	OPT	MOD SET & DIST PNL 8-LINE	7601W4	7602W4	10539.7500	120.0000	20	15
DC76-DA	M019-0DCDA-01626	OPT	EXPAND FOR DC76-A	7602W1	7603W1	24276.2100	144.0000	7	3
DC76-CA	M019-0DCCA-01641	OPT	DATA COMM SYS 115V	7602W1	7603W1	5230.5600	24.0000	7	3
DJ11-AA	M019-0DJAA-01642	OPT	16 ASYCHRONOUS MUX	7602W1	7603W1	5972.6400	76.0000	8	8
DQ11-AB	M019-0DQAB-01636	OPT	A B SELECTOR	7602W1	7603W1	325.5000	6.0000	3	1
DQ11-AB	M019-0DQAB-01637	OPT	A B SELECTOR	7602W1	7603W1	976.5000	18.0000	3	3
DQ11-AB	M019-0DQAB-01638	OPT	A B SELECTOR	7602W1	7603W1	976.5000	18.0000	3	3
DQ11-DA	M019-0DQDA-01635	OPT	EIA UP TO 104KB	7602W1	7603W1	2717.6400	56.0000	4	4
DQ11-EA	M019-0DQEA-01632	OPT	BELL 301/303 TO 250 KB	7602W1	7603W1	2927.0100	45.0000	3	3
DUP11-DA	M019-DUPDA-01625	OPT	INTERFACE SYNCHRONOUS MODEM	7602W1	7603W1	750.5700	15.0000	5	3
DUP11-DA	M019-DUPDA-01640	OPT	INTERFACE SYNCHRONOUS MODEM	7602W1	7603W1	3752.8500	75.0000	27	15
DH11-AA	M019-0DHAA-01679	OPT	PROCESSOR 16 LINE ASSYNC.	7602W2	7603W2	5102.5200	66.0000	4	4
DQ11-DA	M019-0DQDA-01663	OPT	EIA UP TO 104KB	7602W2	7603W2	2038.2300	42.0000	3	3
DQ11-DA	M019-0DQDA-01664	OPT	EIA UP TO 104KB	7602W2	7603W2	2038.2300	42.0000	3	3
DQ11-DA	M019-0DQDA-01662	OPT	EIA UP TO 104KB	7602W2	7603W2	2038.2300	42.0000	3	3

Firm B

DATE RUN 16-MAR-76 M A T E R I A L R E Q U I R E M E N T S P L A N N I N G PAGE: 1
CURRENT WEEK 7603-4 JOB NO:RP26010

*** PLANNED ORDER RELEASE REPORT ***

MANUFACTURED PARTS PLANT:22 SOURCE: 6 WINDOW: 99 WEEKS
RELEASE DATES: 7602W3 - 7802W3

* * * FUTURE DUE RELEASES * * *

PART NUMBER	PART TYPE	DESCRIPTION	------DATES------ RELEASE	DUE	TOTAL STD COST	TOTAL STD HOURS	QUANTITY	LOT SIZE	LEAD TIME	PLANNER
779	PUR	POWER SUPPLY	7605-2	7606-2	201.9500	2.7500	1		4	NONE
			7605-3	7606-3	201.9500	2.7500	1			
			7605-4	7606-4	201.9500	2.7500	1			
			7606-2	7607-1	201.9500	2.7500	1			
			7606-3	7607-2	201.9500	2.7500	1			
			7607-1	7608-1	403.9000	5.5000	2			
			7607-2	7608-2	403.9000	5.5000	2			
			7607-3	7608-3	403.9000	5.5000	2			
			7607-4	7608-4	201.9500	2.7500	1			
M170	MOD	MODULE	7606-5	7607-4	6.0200	.2000	1		4	NONE
M3N3	MOD	MODULE	7606-2	7607-1	129.2000	3.1030	5		4	NONE
			7606-3	7607-2	129.2000	3.1030	5			
			7606-4	7607-3	103.3600	2.4824	4			
			7606-5	7607-4	103.3600	2.4824	4			
M8549-YE	MOD	CACHE ADDRESS SUBSTITUTE MD	7603-5	7604-4	79.1100	.8880	1		4	NONE
			7604-1	7605-1	711.9900	7.9920	9			
			7604-2	7605-2	632.8800	7.1040	8			
			7604-3	7605-3	632.8800	7.1040	8			
			7604-4	7605-4	632.8800	7.1040	8			
			7605-1	7606-1	791.1000	8.8800	10			
			7605-2	7606-2	791.1000	8.8800	10			
			7605-3	7606-3	711.9900	7.9920	9			
			7605-4	7606-4	632.8800	7.1040	8			
			7606-1	7606-5	632.8800	7.1040	8			
			7606-2	7607-1	158.2200	1.7760	2			
			7606-3	7607-2	158.2200	1.7760	2			
			7606-4	7607-3	158.2200	1.7760	2			
			7606-5	7607-4	158.2200	1.7760	2			
			7607-1	7608-1	791.1000	8.8800	10			
			7607-2	7608-2	791.1000	8.8800	10			
			7607-3	7608-3	711.9900	7.9920	9			
			7607-4	7608-4	711.9900	7.9920	9			
			7608-1	7609-1	395.5500	4.4400	5			
			7608-2	7609-2	395.5500	4.4400	5			
			7608-3	7609-3	395.5500	4.4400	5			
			7608-4	7609-4	395.5500	4.4400	5			
			7609-1	7609-5	316.4400	3.5520	4			

Firm B

DATE RUN 16-MAR-76 M A T E R I A L   R E Q U I R E M E N T S   P L A N N I N G PAGE: 1

CURRENT WEEK 7603W4 JOB NO:MP29020

*** ACTION REPORT ***

MANUFACTURED PARTS PLANT: 2 SOURCE:230 WINDOW: 34 WEEKS

SCHEDULE DATES: 7504W2 - 7611W3

PART NUMBER	PART TYPE	DESCRIPTION	LOT SIZE	LEAD TIME	PLANNER	---JOB NUMBER--- -PURCHASE ORDER-	---VENDOR---	---DUE DATE--- SCHED	RESCHED	QTY	RESCHEDULE ACTION
CM11-MA	OPT	MONITOR , TELEPLANT			NONE	M019-0CMMA-01687		7603W4	------	2	CANCEL-
						M019-0CMMA-01696		7603W4	------	2	CANCEL-
CM11-DA	OPT	DISTRIBUTE MODULE			NONE	M019-0CMDA-01483		7512W1	------	3	CANCEL-
CM11-SB	OPT	INPUT SCAN MODULE			NONE	M019-0CMSB-01711		7603W4	------	67	CANCEL-
DC76-DA	OPT	EXPAND FOR DC76-A		4	NONE	M019-0DCDA-01626		7603W1	------	3	CANCEL-
DC76-EA	OPT	DATA COMM SYS 115V		4	NONE	M019-0DCEA-01641		7603W1	------	3	CANCEL-
						M019-0DCEA-01716		7603W4	------	2	CANCEL-
DF11-P	OPT	ACTIVE 20 MA CURRENT LOOP			NONE	M019-0F11P-01701		7603W4	------	4	CANCEL-
DH11-AA	OPT	PROCESSOR 16 LINE ASSYNC.			NONE	M019-0DHAA-00939		7504W2	------	1	CANCEL-
						M019-0DHAA-01444		7511W4	------	1	CANCEL-
						M019-0DHAA-01459		7511W4	------	1	CANCEL-
						M019-0DHAA-01670		7603W2	------	4	CANCEL-
						M019-0DHAA-01673		7603W3	------	4	CANCEL-
						M019-0DHAA-01708		7603W4	------	4	CANCEL-
						M019-0DHAA-01709		7603W4	------	4	CANCEL-
						M019-0DHAA-01710		7603W4	------	4	CANCEL-
						M019-0DHAA-01712		7603W4	------	4	CANCEL-
						M019-0DHAA-01713		7603W4	------	4	CANCEL-
						M019-0DHAA-01715		7603W4	------	4	CANCEL-
						M019-0DHAA-01714		7603W4	------	4	CANCEL-
DH11-AC	OPT	PROCESSOR 16 LINE ASYNC.			NONE	M019-0DHAC-01685		7603W4	------	4	CANCEL-
						M019-0DHAC-01707		7603W4	------	1	CANCEL-
						M019-0DHAC-01692		7603W4	------	4	CANCEL-
						M019-0DHAC-01693		7603W4	------	4	CANCEL-
DH11-AD	OPT	16 LINE MUX MODEM H317A P			NONE	M019-0DHAD-01679		7603W4	------	4	CANCEL-
						M019-0DHAD-01680		7603W4	------	4	CANCEL-
						M019-0DHAD-01704		7603W4	------	4	CANCEL-
						M019-0DHAD-01705		7603W4	------	4	CANCEL-
DH11-AE	OPT	16 LINE MUX H317B PNL			NONE	M019-0DHAE-01691		7603W4	------	4	CANCEL-
DJ11-AA	OPT	16 ASYCHRONOUS MUX			NONE	M019-0DJAA-01642		7603W1	------	8	CANCEL-
						M019-0DJAA-01682		7603W4	------	1	CANCEL-

Firm C

04/02/76 REQUIREMENTS GENERATION PAGE 071

	615	620	625	630	635	640	645	650	655	660
GROSS	2	2	2	2	602	2	602	2	2	2
OPEN ORD										
NET	2	2	2	2	602	2	602	2	2	2
PLAN ORD										

	665	670	675	680	685	690	695	700	705	710
GROSS	2	2	2	2	2	2				
OPEN ORD										
NET	2	2	2	2	2	2				
PLAN ORD										

ITEM 06-132250-300 01 DESC GAS SEAL U/M# PCS ORDPOLCD# A ITEMTYP# 2 VALUE# B LOTMCD # M

ONHAND # 715 ALLOC# 0 ORDQTY# 0 MIN# 0 CRYRAT# .005 UNITCST# .0808 LOTMPUR# 0

SFTYSTK# 0 AVAIL# 715 MULT # 0 STORE# C SHRINK# .00 SFTUPCST# .00 LOTMMFG# 35

	565	570	575	580	585	590	595	600	605	610
GROSS		18	109	109	109	109	109	109	109	109
OPEN ORD										
NET									66	109
PLAN ORD		66	109	109	109	109	109	109	109	109

	615	620	625	630	635	640	645	650	655	660
GROSS	109	109	109	109	109	109	109	109	109	109
OPEN ORD										
NET	109	109	109	109	109	109	109	109	109	109
PLAN ORD	109	109	109	109	109	109	109			

	665	670	675	680	685	690	695	700	705	710
GROSS	109	109	109	109						
OPEN ORD										
NET	109	109	109	109						
PLAN ORD										

ITEM 06-132269-300 01 DESC COLLAR U/M# PCS ORDPOLCD# A ITEMTYP# 2 VALUE# C LOTMCD # M

ONHAND # 418 ALLOC# 0 ORDQTY# 0 MIN# 0 CRYRAT# .005 UNITCST# .2414 LOTMPUR# 0

SFTYSTK# 0 AVAIL# 418 MULT # 0 STORE# A SHRINK# .00 SFTUPCST# .00 LOTMMFG# 35

	565	570	575	580	585	590	595	600	605	610
GROSS	572	109	109	109	109	109	109	109	109	109
OPEN ORD										
NET	254	109	109	109	109	109	109	109	109	109
PLAN ORD	1,017	109	109	109	109	109	109	109	109	109

Firm C

PURCHASING OPEN ORDERS DUE WITHIN THE REVIEW TIME

** PURCHASING REVIEW TIME # 10 SHOP DAYS **

ORDER	NO.	ITEM NUMBER	DESCRIPTION	AVAIL INV.	DUE DATE	ORDER QTY	NEW	DATE --	QTY
01	48756	00-100268-000 01 00	.023 DIA 1175 F SOLDER	10	575	35	**	*	**
10	48555	00-100294-C00 01 00	.033 DIA 670 F SOLDER		554	6	**	*	**
03	49361	00-100302-C00 01 00	60 MESH SIL BRZG ALLOY		555	500	**	*	**
20	48781	00-100304-000 01 00	.050 DIA 361 F S SOLDER		574	15	**	*	**
16	47426	00-100313-000 01 00	.036 DIA MULTICORE SLDR	1	505	10	**	*	**
32	45551	00-100334-000 01 00	.035 MILD STL WELD WIRE	525	489	475	**	*	**
32	45551	00-100334-000 01 00	.035 MILD STL WELD WIRE	525	509	500	**	*	**
32	45551	00-100334-000 01 00	.035 MILD STL WELD WIRE	525	548	500	**	*	**
32	45551	00-100334-000 01 00	.035 MILD STL WELD WIRE	525	573	500	**	*	**
01	46817	00-100501-C00 01 00	.003 X .781 X 2 IN MICA	44	570	50	**	*	**
01	46818	00-100503-C00 01 00	.0035 X 2 X 2 IN MICA	70	549	25	**	*	**
01	44683	00-100511-C00 01 00	.003 X .906 X 2 IN MICA		529	50	**	*	**
01	47286	00-102002-000 01 00	5/8 X 3/4 BRASS BAR	218	528	327	**	*	**
01	48793	00-102002-000 01 00	5/8 X 3/4 BRASS BAR	218	550	230	**	*	**
01	48789	00-102008-C00 01 00	1/2 HEX BRASS	240-	565	750	**	*	**
01	48664	00-102012-000 01 00	7/8 HEX BRASS BAR	358	569	3000	**	*	**
01	48577	00-102013-000 01 00	1 HEX BRASS BAR	3161-	554	310	**	*	**
01	48577	00-102013-000 01 00	1 HEX BRASS BAR	3161-	568	5000	**	*	**
01	49197	00-102037-C00 01 00	9/16 IN DIA BRASS ROD	52	569	1000	**	*	**
01	47288	00-103006-000 01 00	5/8 DIA SAE1213/1215 CS	1019	549	1543	**	*	**
01	47790	00-103006-000 01 00	5/8 DIA SAE1213/1215 CS	1018	530	196	**	*	**
01	47790	00-103006-C00 01 00	5/8 DIA SAE1213/1215 CS	1018	569	3000	**	*	**
70	48574	00-103077-000 01 00	.375 DIA SAE 1018 CS	45-	569	5000	**	*	**
12	48784	00-103527-C00 01 00	1/32 X 1 IN SAE 1010 CS	8	570	150	**	*	**
23	48832	00-103566-C00 01 00	.031X5/8 C R STRIP	63	549	8	**	*	**
40	48764	00-103586-C00 01 00	.030 X 2 5/16 C1074 CS		564	700	**	*	**
33	48871	00-103596-C00 01 00	1/16X 3-5/8 SAE1010 CRS	6	574	25	**	*	**
12	48926	00-103612-000 01 00	.050 X 6 SAE 1010 CRS	72	570	2000	**	*	**
70	48733	00-103634-000 01 00	.047 X 3.750 SAE 1010CS	40	564	1000	**	*	**
70	48525	00-103637-000 01 00	.102 X 2 X 6 GALV STEEL	2300-	569	2000	**	*	**
70	48351	00-103638-000 01 00	.050 X 7.750 SAE 1010CS		529	14000	**	*	**
03	48479	00-10407C-C00 01 00	5/8 TYPE 321 SST ROD	259	570	1200	**	*	**
01	48790	00-104116-000 01 00	19/32 DIA 303 SST	167-	580	1500	**	*	**
03	48923	00-104119-000 01 00	5/8 DIA. 303 SST ROD	433	580	600	**	*	**
40	48603	00-104133-C00 01 00	9/16 HEX 316 SST BAR	110	570	300	**	*	**
71	48956	00-104200-C00 01 00	.062 DIA TYPE 304SS ROD		559	5	**	*	**
01	49339	00-104243-000 01 00	5/8 DIA TYPE 304 SS ROD	853	579	1000	**	*	**
03	47400	00-104244-000 01 00	.594 DIA 17-4 PH SS ROD	450	505	550	**	*	**
70	48559	00-104502-C00 01 00	.032 X 3 IN 302-304 SST	3470	563	50	**	*	**
11	41664	00-104506-C00 01 00	.062 X .750 302-304 SST	2562	569	1500	**	*	**
18	49405	00-104577-C00 01 00	.032 X .375 302-304 STP		574	10	**	*	**
08	48692	00-104705-C00 01 00	.010 X .281 302-304 SST		550	10	**	*	**
11	44756	00-105020-C00 01 00	ALUM BRONZE ROD		549	1000	**	*	**
01	44749	00-105044-000 01 00	3/16 DIA 36 X NI FE ROD	218	569	262	**	*	**
70	48219	00-105237-000 01 00	.625 DIA WOODEN DOWEL	334	529	666	**	*	**
32	48937	00-105514-C00 01 00	1.375 HEX 2024-T351 AL	144	568	600	**	*	**
70	48409	00-105529-C00 01 00	.031X 9.150 3003-H14 AL		569	500	**	*	**
70	47463	00-105531-000 01 00	.040 X 9 3003-0 AL STP	6600-	539	1078	**	*	**
70	47468	00-105531-C00 01 00	.040 X 9 3003-0 AL STP	6600-	569	6500	**	*	**
01	47123	00-106002-C00 01 00	.620 OD X .565 ID BRASS	1427-	544	1539	**	*	**
01	48654	00-106002-000 01 00	.620 OD X .565 ID BRASS	1427-	580	1500	**	*	**
01	48974	00-106002-000 01 00	.630 OD X .565 ID BRASS	1427-	565	1500	**	*	**
01	08555	00-106002-000 01 00	.620 OD X .565 ID BRASS	1427-	567	1524	**	*	**
03	44751	00-106029-000 01 00	.619 ODX.586 ID 321 SST	565	580	139	**	*	**

Firm C

PC-40 PLANNED ORDER REPORT PERIOD DUE 570

PART NUMBER	SC	DESCRIPTION	ENDPG		*OVDUE ORDERS	*570* QTY	*575* QTY	*580* QTY	*585* QTY	*590* QTY	TOTAL QTY
00-103503-000	01	.042 X 9/16 SAE 1	11	P	200						200
06-030000-000	01	SURFACE MOUNTING	11	M		2000			2000		4000
06-030000-049	01	SURFACE MOUNTING	11	M						1000	1000
06-030002-000	01	SURFACE MOUNTING	11	M	2000	2000		2000	2000		8000
06-110006-000	01	SOLID SILVER CON	11	P			100000				100000
06-130000-000	01	BRIDGE	11	M						20000	20000
06-130005-000	01	BINDING POST LONG	11	P						60000	60000
06-130033-000	01	COLLAR - 1 PRONG	11	M					60000		60000
06-135446-000	01	CONTACT	11	P	30000						30000
06-137238-000	01	STRUT	11	M				30000			30000
06-250000-013	01	ADJ SCREW - REGUL	11	M					15000		15000
06-250000-056	01	ADJUSTING SCREW	11	M	15000						15000
06-250001-301	01	COVER 1/4 42 NS 2	11	M		5000					5000
06-250001-007	01	COVER 1/4-28 NS2	11	M			10000				10000
06-250030-001	01	HEX NUT	BL 11	P	300000						300000

Firm C

MATERIAL SHORTAGE REPORT DETAIL

PARENT ITEM NUMBER 04-035100-005 01 DESCRIPTION CONNECTOR ORD QTY 1000 START DATE 580

COMP ITEM NUMBER	DESCRIPTION	ON HAND	- ALLOC	# AVAIL	P/M	ON ORDER	DUE DATE	QTY/PER	SHORTAGE
04-035104-001	CONNECTOR ADAPTOR	391	2	389	M			1	611

PARENT ITEM NUMBER 04-035100-005 01 DESCRIPTION CONNECTOR ORD QTY 1000 START DATE 585

COMP ITEM NUMBER	DESCRIPTION	ON HAND	- ALLOC	# AVAIL	P/M	ON ORDER	DUE DATE	QTY/PER	SHORTAGE
04-035104-001	CONNECTOR ADAPTOR	391	2	389	M			1	611

PARENT ITEM NUMBER 04-035104-001 01 DESCRIPTION CONNECTOR ADAPTOR ORD QTY 3000 START DATE 570

COMP ITEM NUMBER	DESCRIPTION	ON HAND	- ALLOC	# AVAIL	P/M	ON ORDER	DUE DATE	QTY/PER	SHORTAGE
06-124408-000	ELFCTRICAL CONNECTOR IN	683	0	683	M 92981	2000	589	1	2317

PARENT ITEM NUMBER 04-035104-001 01 DESCRIPTION CONNECTOR ADAPTOR ORD QTY 1000 START DATE 590

COMP ITEM NUMBER	DESCRIPTION	ON HAND	- ALLOC	# AVAIL	P/M	ON ORDER	DUE DATE	QTY/PER	SHORTAGE
06-124408-000	ELECTRICAL CONNECTOR IN	683	0	683	M 92981	2000	589	1	317

Firm E

01/15/75 [redacted] REQUIREMENTS GENERATION PAGE 91

ITEM 22537 DESC CUP HTR TERM/269

REV 0 U/M EA ITEM-TYPE 4 STD-COST .6700 INV-CLSS STK-ROOM 30

ONORD-PURCH 435 ONORD-IOR ONORD-MKE ORDPOL A ORDQTY PUR-LD 55 MFG-LD MFG-OR-PUR

BALOH 202 SFTSTK ALLOC QTY-IN-INSP 430 ACCT-NO 11610 020 SHRNKF .00 USAGE-YTD 588

	1/14/75	1/21/75	1/28/75	2/04/75	2/11/75	2/18/75	2/25/75	3/04/75	3/11/75
GROSS	25	80		82			107	107	
SHED REC	430			435					
NET REQ									
PLAN ORD									
PRJ BAL	607	527	527	880	880	880	773	666	666

	3/25/75	4/01/75	4/08/75	4/15/75	4/22/75	4/29/75	5/06/75	5/13/75	5/20/75
GROSS	80		80				172		
SHED REC									
NET REQ									
PLAN ORD					33			129	
PRJ BAL	586	586	506	506	506	506	334	334	334

	6/03/75	6/10/75	6/17/75	6/24/75	7/01/75	7/08/75	7/15/75	7/22/75	8/12/75
GROSS		206				161			129
SHED REC									
NET REQ						33			129
PLAN ORD		86							
PRJ BAL	334	128	128	128	128	33-	33-	33-	162-

	8/26/75	9/02/75	9/09/75	9/16/75	9/23/75	9/30/75	10/07/75	10/14/75	10/21/75
GROSS			86						
SHED REC									
NET REQ			86						
PLAN ORD									
PRJ BAL	162-	162-	248-	248-	248-	248-	248-	248-	248-

	11/04/75	11/11/75	11/18/75	11/25/75	12/02/75	12/09/75	12/16/75	12/23/75	12/30/75
GROSS									
SHED REC									
NET REQ									
PLAN ORD									
PRJ BAL	248-	248-	248-	248-	248-	248-	248-	248-	248-

MRP 7-6.0

Firm I

[redacted] PLANNED ORDERS BUY RUN DATE 01/15/75

PART #	DESCRIPTION	01/14/75	01/21/75	01/28/75	02/04/75	02/11/75	50 WEEKS
11603-68	8-32X2 5/16 FL SC					84	1298
21792	TERMINAL HTR/233					43	484
21804	EXH TUB/233/269/281				18	108	1417
21972	OUTPUT TRANSFORMER		78				579
21973	"A" VANE ANODE	166				1136	8726
21974	BLOCK ANODE		15				536
21981	INSULATOR HTR/22018			150	97		989
22157	TERMINAL LUG				126		1174
22448-2	SPACER CATHODTE 233	624		96		96	1650
22459	LABEL IDENT MA239&281	169		44			745
22632	MAGNET MA269	20			168		430
22633	ISOL BODY /269/22640			20			151
22637	COVER CHOKE/269	232					605
22647	SPACER HEATER/269	18	430			345	1023
22693	CATHODE SPACER/269					63	1324
22713	LABEL/233	14		21			392
98133	LEAD WIRE GREEN	27			20		386
98137	WIRE #20 YEL KYNAR INS	131	20			20	491
98138	LEAD WIRE YELLOW	27			20		386

MRP 7-7.0

Firm F

06/28/74 MRP EXCEPTION REPORT PAGE 2

PART NO	EXCEPTION CODE	REQMT / ORDER DUE DATE	QUANTITY	MESSAGE
43577	06	07/18/74	188	MOVE IN
40577	19	07/25/74	500	
850255	06	07/19/74	85	
850265	19	08/15/74	150	
850266	06	07/18/74	100	
850265	19	08/15/74	150	
850621	06	07/25/74	200	
850621	13	08/15/74	220	
850622	06	07/25/74	200	
850622	19	08/15/74	220	
850523	06	07/25/74	200	
850523	19	08/15/74	220	
850583	06	07/25/74	287	
850683	06	06/27/74	387	
850633	19	07/18/74	500	
850683	19	08/15/74	500	
850686	06	07/18/74	300	
850536	06	06/20/74	400	
850685	19	08/15/74	500	
850686	19	07/18/74	500	
85033C	06	07/18/74	295	
85083C	06	06/20/74	395	
850810	19	07/18/74	500	
850630	19	08/15/74	500	
850831	06	07/25/74	233	
850831	06	06/27/74	333	
853331	19	07/18/74	500	
852331	19	08/15/74	500	
85454-2	06	07/18/74	200	
95454-2	19	07/25/74	400	
85455-3	06	07/18/74	200	
85455-3	19	07/25/74	400	
85470-13	06	07/25/74	200	
85470-18	19	08/15/74	220	
85470-19	06	07/25/74	200	
95470-19	19	08/15/74	220	

NO OF EXCEPTIONS GROUP TOT 36

Firm E

ORDERS WITH INVALID COMPLETION DATES

ORDER NO	PART NO	BAL DUE	DIV	SCH DATE
C00814	22525	27	30	052574
C00815	22511	61	30	052574
C00816	22642	91	30	052574
C00817	22686	95	30	052574
C00818	22695	82	30	052574
R23780	33311-3	1000	30	0
13150	83840	40	30	0
459395	96710	250	30	072974
459953	22134	25	30	050474
462676	QUART #1	5	30	060174
463322	41470-1	700	30	060174
463843	22632	1500	30	091574

MRP 7-4.0

Firm E

05/03/74 SHORTAGE REPORT PAGE 10

STOCKROOM 11 31V 44

ASSEMBLY NO	PART NO	P/A	DESCRIPTION	ON HAND	ALLOC		04/29	05/06	05/13	05/20	05/27	BEYOND
	646736-2	4	COMP RING	65	210	NEED	145			202		1292
						SCHED REC		2000				
MATL103	627308-1	4	POLE PIECE			NEED		100				5756
						SCHED REC		10000				
MATL104	627308-1	4	POLE PIECE			NEED		100				5756
						SCHED REC		10000				
MATL135	639773	4	CIRCUIT		105	NEED						
						SCHED REC						
MATL184	612039-1	4	CONNECTOR	336	210	NEED				74		1294
						SCHED REC						3000
	629695-2	4	TERMINATION	369	70	NEED				59		129
						SCHED REC		250				1250
MATL188	626952-1	4	STUB	449	252	NEED		7	350			
						SCHED REC			1000			
	627960	4	FERRITE		126	NEED	126	136	192			
						SCHED REC			250			250
	628833	4	CAN		63	NEED	63		62			
						SCHED REC		150				
	629010	4	GROUND PLANE		126	NEED	126		124			
						SCHED REC		250				
	629011-1	4	SHUNT	21	63	NEED	42		62			
						SCHED REC			300			
	629011-2	4	SHUNT	55	63	NEED	8		62			
						SCHED REC			300			
MATL201	626318-1	4	MAGNET			NEED			124			1052
						SCHED REC						1000
	626692	4	POLE PIECE	30		NEED			94			
						SCHED REC						
	626951-1	4	TUNING STUB			NEED			248			
						SCHED REC			500			
MATL221	626318-40	4	MAGNET			NEED					468	128
						SCHED REC		684				2500
	629695-2	4	TERMINATION	369	70	NEED				59		129
						SCHED REC		250				1250
MATL231	633114	4	BOTTOM SHUNT	140	140	NEED		252	252	212		240
						SCHED REC						
MATL252	612039-1	4	CONNECTOR	338	210	NEED				74		1294
						SCHED REC						3000

Firm F

08/30/74 BUYER PLANNER ACTION PAGE 2

BUYER CODE K

PART NO	DESCRIPTION	PURCHASE ORDER NO	MOVE IN VENDOR NAME	QTY IN INSP	BALANCE DUE QTY	BALANCE DUE DATE	MRP QTY	NEED DATE	IMMEDIATE NEED
617638-14	SHUNT	470748	TYWOOD		100	09/13/74	12	09/06/74	
				BEYOND					
626254-6	COMP RING	470749	TYWOOD		500	09/13/74	22	09/06/74	20
				BEYOND					20
626359-5	FERRITE	470753	QUARTZITE PROCE		30	09/13/74	22	08/30/74	
				BEYOND					
626361-12	MAGNET	470754	QUARTZITE PROCE		30	09/20/74	22	08/30/74	
				BEYOND					
626765-23	FERRITE	470757	QUARTZITE PROCE		400	09/06/74	245	08/30/74	
					400	09/20/74	210	09/13/74	
					500	10/04/74	420	09/20/74	
							420	10/18/74	
				BEYOND					
626765-30	FERRITE	465970	QUARTZITE PROCE	151	352	09/06/74	4	08/30/74	216
							32	09/06/74	
							160	09/20/74	
				BEYOND			508		
626793-3	FERRITE	470759	QUARTZITE PROCE		250	09/20/74	40	08/30/74	32
					750	10/04/74	202	09/20/74	
							106	10/18/74	
				BEYOND			30		
626855-1	FERRITE & DIELECTRIC	469092	TRANS TECH INC		250	09/17/74	22	09/06/74	12
					250	10/01/74	298	09/20/74	
							42	10/04/74	
							42	11/01/74	
				BEYOND			84		
626976-1	SHUNT CLIP	470438	TYWOOD		125	09/06/74	4	08/30/74	70
							1	09/13/74	
							3	09/20/74	
				BEYOND					
627308-3	POLE PIECE	470761	TYWOOD		500	08/30/74	192	09/13/74	1640
					2500	09/06/74	324	09/20/74	
				BEYOND			5324		
627806	CONN	467829	AMERICON CORP		250	09/04/74	265	08/30/74	
					550	09/13/74	210	09/13/74	
					500	09/20/74	464	09/20/74	
							420	10/18/74	
				BEYOND					
628269-4	CONN	465702	DELTA ELECTRONI		600	09/06/74	48	09/13/74	13
				BEYOND			1217		13
628714	CAN ASSY	470992	TYWOOD CORP		15	09/13/74	11	08/30/74	
				BEYOND					

MRP 7-11.0

Firm E

TIME PHASED MRP MASTER SCHEDULE 09/16/74

DIV	STKRM	S/O #	CUSTOMER	ASSY-PARTNO	DUE DATE	QTY	CODE	
3C	30	TRS-37	ORD 41 FCST 5	MA1835A	10/14/74	46	2	MRP
3C	30	TRS-38	ORD 2152 FCST 646	MA1858A	09/16/74	139	2	MRP
3C	30	TRS-38		MA1858A	09/30/74	125	2	MRP
3C	30	TRS-38		MA1858A	10/14/74	125	2	MRP
3C	30	TRS-38		MA1858A	10/28/74	125	2	MRP
3C	30	TRS-38		MA1858A	11/11/74	125	2	MRP
3C	30	TRS-38		MA1858A	11/18/74	100	2	MRP
3C	30	TRS-38		MA1858A	12/02/74	125	2	MRP
3C	30	TRS-38		MA1858A	12/16/74	125	2	MRP
3C	30	TRS-38		MA1858A	12/30/74	125	2	MRP
3C	30	TRS-38		MA1858A	01/13/75	125	2	MRP
3C	30	TRS-38		MA1858A	02/03/75	1454	2	MRP
3C	30	TRS-39	ORD 270 FCST-	MA1863A	09/30/74	80	2	MRP
3C	30	TRS-39		MA1863A	12/09/74	150	2	MRP
3C	30	TRS-40	ORD 943 FCST 1000	MA1863B	10/07/74	130	2	MRP
3C	30	TRS-40		MA1863B	10/14/74	130	2	MRP
3C	30	TRS-40		MA1863B	12/02/74	125	2	MRP
3C	30	TRS-40		MA1863B	12/09/74	125	2	MRP
3C	30	TRS-40		MA1863B	01/13/75	1287	2	MRP
3C	30	TRS-1	ORD- FCST 1000	MA303	02/03/75	1000	2	MRP
3C	30	TRS-2	ORD48 FCST 100	MA3068	09/16/74	36	2	MRP
3C	30	TRS-2		MA3068	12/16/74	78	2	MRP
3C	30	TRS-18	ORD- FCST 32 10	MA3154	/ /		2	MRP

MRP 7-3.0

SCHEDULE DATE NOT NUMERIC
QUANTITY NOT NUMERIC
THIS RECORD BYPASSED

3C	30	TRS-19	ORD 158 FCST 10	MA3157D	10/07/74	112	2	MRP
3C	30	TRS-20	ORD- FCST 50	MA3160	12/16/74	50	2	MRP
3C	30	TRS-21	ORD 87 FCST 13	MA3162	09/16/74	16	2	MRP
3C	30	TRS-23	ORD 83 FCST 17	MA3163	09/16/74	47	2	MRP
3C	30	TRS-23		MA3163	10/14/74	25	2	MRP
3C	30	TRS-23		MA3163	12/16/74	7	2	MRP
3C	30	TRS-24	ORD 91 FCST 5	MA3191	09/16/74	72	2	MRP
3C	30	TRS-27	ORD- FCST 9	MA3215	12/16/74	9	2	MRP
3C	30	TRS-28	ORD- FCST 6	MA3215-1	12/16/74	6	2	MRP
3C	30	TRS-3	ORD 230 FCST 250	MA3408	09/30/74	120	2	MRP
3C	30	TRS-3		MA3408	10/07/74	120	2	MRP
3C	30	TRS-3		MA3408	12/16/74	140	2	MRP
3C	30	TRS-4	ORD 12 FCST 138	MA340D	12/16/74	100	2	MRP
3C	30	TRS-5	ORD 45 FCST 55	MA340MIF	10/07/74	65	2	MRP
3C	30	TRS-5		MA340MIF	12/16/74	35	2	MRP
3C	30	TRS-6	ORD 49 FCST 100	MA340T	10/07/74	55	2	MRP
3C	30	TRS-6		MA340T	12/16/74	88	2	MRP
3C	30	TRS-7	ORD 808 FCST 820	MA3498	11/04/74	120	2	MRP
3C	30	TRS-7		MA3498	11/11/74	180	2	MRP
3C	30	TRS-7		MA3498	11/25/74	100	2	MRP
3C	30	TRS-7		MA3498	12/02/74	110	2	MRP

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INV113 10-1
RUN DATE: 01/17/76

[redacted]
STOCK STATUS REPORT WEEK 612

PAGE 20
AS OF MDAY 316
01/18/76

*ITEM NUMBER	*DESCRIPTION*	*INVENTORY DATA*		*L/T-WEEKS*		*ORDER DATA*		*COST DATA*		*MISCELLANEOUS*	
001 11-01509CC-000	TRANS.SI,NPN,EPOXY MPS6521	ITEM TYPE	4	PRIMARY	04	ORD.POLICY	4	TOTL STD CST	[redacted]	ENG.DWG.NO	110150900000
		ITEM STAT.	2	REVIEW	01	SAFETY STK	50	STD MTL CST	[redacted]	REV.	
PLANNER 31		ABC CODE	B	VENDOR	06	LOT SIZE		MTL COST CODE	3	SIZE	4
		INV CLASS	05	FACTORY	01	MIN QTY		MTL COST QTY		PROJ.INV.12MOS.	12755
TOTAL COM 2229		SER LEVEL	00	SECOND	00	MAX QTY		DATE LST CHG	06/02/75	ALLOW FACTOR	.00
UNIT/MEAS EACH		WK/BY CDE	8			ROUNDING					

STOCKROOM DATA

STOCKROOM NO	STOCK LOCATION	ON HAND BAL		RECEIPTS	RETURNS	PLN ISS	UNPL ISS	ADJUST		
020		2229	LAST WEEKS TRANS	1600	193	300	75	411	INVENTORY COUNT	3309
			DATE LAST TRANS	121675	91075	10776	11476	122975	DATE LAST COUNT	122975
			QTY OF LAST TRAN	0	0	0	75	0	TRAN LAST COUNT	86

REQUIREMENTS EXPLOSION

WEEK NO	PAST	612	613	614	615	616	617	618	619	620	621	622	623	624	TOTAL
PLN REQ	0	420	0	300	0	1000	300	900	0	300	0	550	600	310	4680
UNPL REQ	0	0	0	0	0	400	0	600	0	0	0	0	0	0	1000
SCH REC	0	0	2250	0	0	0	0	0	0	0	0	0	0	0	2250
PROJ INV	2179	1759	4009	3709	3709	2309	2009	509	509	209	209	341-	941-	1251-	1251-
NET REQ	0	0	0	0	0	0	0	0	0	0	0	341	600	310	1251
PLN REC	0	0	0	0	0	0	0	0	0	0	0	341	600	310	1251
PLN REL	0	0	0	341	600	310	800	0	0	0	0	100	0	0	2151
PLN INV	2179	1759	4009	3709	3709	2309	2009	509	509	209	209	0	0	0	0

WEEK NO	625	626	627	628	629	630	631	632	637	641	645	650	711	FUT	TOTAL
PLN REQ	800	0	0	0	0	100	0	0	0	0	0	0	0	0	900
UNPL REQ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SCH REC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PROJ INV	2351-	2051-	2051-	2051-	2051-	2151-	2151-	2151-	2151-	2151-	2151-	2151-	2151-	2151-	2151-
NET REQ	800	0	0	0	0	100	0	0	0	0	0	0	0	0	900
PLN REC	800	0	0	0	0	100	0	0	0	0	0	0	0	0	900
PLN REL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PLN INV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

HISTORY - WEEKS

	PER TO DATE	PERIOD	PERIOD	PERIOD	QTR	QTR	QTR	QTR	12MOS	TOTAL	WKLY AVE
PLAN ISSUES	1300	1033	0	0	6345	2600	0	0	8945	11278	322
UNPL ISSUES	1292	3	0	0	418	436	0	0	854	2149	61
RECEIPTS	3600	0	0	0	5000	5000	0	0	10000	13600	388
RETURNS	0	0	0	0	193	11	0	0	204	204	5
ADJUSTMENTS	193	14	0	0	29	0	0	0	29	236	6
NET	1201	1022	0	0	1541	1975	0	0	434	413	17

OPEN ORDERS DETAIL - WEEKS

VENDOR NAME	ORDER NO	QTY DUE SLIP	VENDOR NAME	ORDER NO	QTY DUE SLIP	VENDOR NAME	ORDER NO	QTY DUE SLIP
RO	P029476	2250 615 612						

REQUIREMENTS DETAIL - WEEKS

*ORDER NO	QTY	DUE	*ORDER NO	QTY	DUE	*ORDER NO	QTY	DUE	*ORDER NO	QTY	DUE
0345037	400	612	0422015	20	612	3045038	300	614	0030014	430	616
C345039	400	614	0429025	600	616	3045040	300	617	0300018	500	618
3344024	300	618	7414027	600	618	0048032	300	620	0429026	430	622
0453002	150	622	0045041	600	623	3044025	300	624	0220001	10	624
3345042	400	625	0429027	400	625	0210025	130	630			

Firm F

(PLN050-05) CAPACITY PLANNING - AEP RUN DATE 1/29/74 PAGE 68

TEST SUMMARY - ALL PRODUCTS ——— BAR GRAPH ———

TEST WEEK	TEST IN ASP SCHEDULE DOLLARS
413	9,595
414	94,531
415	342,397
416	517,980
417	327,255
418	355,129
419	496,572
420	555,549
421	453,236
422	435,531
423	417,592
424	435,721
425	435,333
426	414,410
427	465,176
428	457,550
429	436,628
430	325,599
431	395,234
432	323,178
433	349,153
434	313,451
435	309,334
436	335,613
437	102,530
438	55,925
439	45,145
440	21,113
441	15,100
442	36,700
443	39,000
444	0
445	3,750
448	13,313
449	12,148
450	0
TOTAL	$ 9,279,546*

0 I 100K I 200K I 300K I 400K I 500K I 600K I 700K I 800K I

Firm F

RUN DATE 10/17/75 PLANNER RESCHEDULE REPORT WEEK 551 AS OF DATE 10/20/75

PLNR NO		ITEM NUMBER	ITEM DESCRIPTION		PRI LT	TOO LATE INTERVAL 1	1	6	5	8	TOO EARLY 8	250	250	250
004	001	71-0525501-000	BRD.PRINTED WIRING	ADC102	13	A	B							
004	001	71-0530300-000	BRD.PRINTED WIRING	5491	10	A	B							
004	001	71-0531702-000	BRD.PRINTED WIRING	SHAS	11		B		D					
004	001	71-[illegible]-000	BRD.PRINTED WIRING	SH[illegible]1A	10		B							
004	001	71-0543[illegible]-000	BRD.PRINTED WIRING	ADC12C[illegible]	11		B	C						
004	001	71-0557102-000	BRD.PRINTED WIRING	ADC/CZ	14			C						
004	001	71-0551750-000	BRD.PRINTED WIRING	502,932	13		B	C	D					
004	001	71-0552700-000	BRD.PRINTED WIRING	935	13				D					
004	001	71-056[illegible]300-000	BRD.PRINTED WIRING	5960	12			C						
004	001	71-05[illegible]0300-000	BRD.PRINTED WIRING	ADC/CU	12			C						
004	001	71-[illegible]3001-000	BRD.PRINTED WIRING	SHA3	10			C						
004	001	71-[illegible]515301-000	BRD.PRINTED WIRING	CAC12C	10	A	B							
004	001	71-0617500-000	BRD.PRINTED WIRING	DAC/CS	12			C						
004	001	71-0616[illegible]32-000	BRD.PRINTED WIRING	AD2010 CONVERTER	10				D					
004	001	71-0620[illegible]-000	BRD.PRINTED WIRING	AD2010 CONNECTOR	12	A	B	C	D					
004	001	71-0[illegible]0401-000	BRD.PRINTED WIRING	AD2010 CONNECTOR	12								B	
004	001	71-[illegible]23300-000	BRD.PRINTED WIRING	233	12								B	
004	001	71-0[illegible]7201-000	BRD.PRINTED WIRING	A-2008 PWR SUPPLY	12				D					
004	001	71-0[illegible]3301-000	BRD.PRINTED WIRING	AD2008 LOGIC	12							A		
004	001	71-0640000-000	BRD.PRINTED WIRING	5930,5902	10			C	D					
004	001	71-0614[illegible]01-000	BRD.PRINTED WIRING	275	12			C						
004	001	71-0[illegible]7701-000	BRD.PRINTED WIRING	[illegible]1125	11	A	B	C	D					
004	001	71-0730700-000	BRD.PRINTED WIRING	233	12			C	D					
004	001	71-07[illegible]02-000	BRD.PRINTED WIRING	CAC1122	10				D					
004	001	71-0711900-000	BRD.PRINTED WIRING	CAC1138	10			C	D					
004	001	71-0732[illegible]-000	BRD.PRINTED WIRING	CAS1120	10				D					
004	001	71-0742[illegible]00-000	BRD.PRINTED WIRING	451R	13	A	B							
004	001	72-0[illegible]-000	PIN	.325 X .040 X .052	10			C						
004	001	72-0[illegible]-000	PIN	.450 X .040 X .031	10		B	C						
004	001	72-0[illegible]-000	PIN	.604 X .040 X .031	10			C						
004	001	72-0155107-000	PIN	.785 X .032 X .031	10		B	C						
004	001	72-0[illegible]-000	PIN	.519 X .040 X .031	10	A								
004	001	73-0127[illegible]-000	CASE		08		B	C						
004	001	73-0177[illegible]-000	HEADER		07							A		
004	001	73-0134[illegible]-000	CASE		10		B							
004	001	73-01[illegible]-000	HEADER		09		B	C						
004	001	73-01[illegible]-000	CASE		10							A		
004	001	73-0270[illegible]-000	CASE	1.5 X 1.5 X 0.4	10			C						
004	001	73-0270[illegible]-000	HEADER		10	A	B					A		
004	001	73-0228[illegible]-000	CASE		08	A								
004	001	73-0228[illegible]-000	HEADER		09	A								
004	001	73-0237701-000	CASE	1.5X1.5X0.625	09			C						
004	001	73-025[illegible]701-000	CASE	2.5 X 3.5 X 1.25	08		B	C						
004	001	73-025[illegible]264-000	CASE		08		B	C						
004	001	73-025[illegible]265-000	HEADER		08		B	C						
004	001	73-025[illegible]267-000	HEADER		08	A	B	C						
004	001	73-025[illegible]269-000	HEADER		10			C				A		
004	001	73-0272103-000	CASE ALUM PAINTED		12	A	B	C	D					
004	001	73-0465301-000	CASE	2.0 X 2.0 X 0.4	10									C
004	001	73-0465302-000	HEADER		10	A	B	C						

Firm F

INV110 02 [redacted] PAGE 1

AS OF M-DAY 151

RUN DATE : 06/04/75 PURCHASE ORDERS WITH NO REQUIREMENTS WEEK 531 06/02/75

ITEM NUMBER	DESCRIPTION	P.O. NO.	VENDOR NAME	QTY	SHIP	SLIP
001 11-0122000-000	TRANS.SI,NPN,EPOXY 2N3415	PO28419	GERHER	25	531	531
001 33-0027322-000	RES.,FXD MET. FILM 73.2K 1% 50PPM 1/8W	PO29119	MEPCO	300	543	543
001 33-0031783-000	RES.,FXD MET. FILM 178K 1% 100PPM 1/8W	II29004	MEPCO	200	529	
001 33-0032212-000	RES.,FXD MET. FILM 22.1K 1% 100PPM 1/8W	PO29113	RAMPART	100	530	530
001 33-0033489-000	RES.,FXD MET. FILM 34.8 1% 100PPM 1/8W	PO29117	MEPCO	300	531	531
001 33-0035230-000	RES.,FXD MET. FILM 523 1% 100PPM 1/8W	PO29117	MEPCO	300	531	531
001 33-0035900-000	RES.,FXD MET. FILM 590 1% 100PPM 1/8W	PO29114	RAMPART	100	530	530
001 33-0036819-000	RES.,FXD MET. FILM 68.1 1% 100PPM 1/8W	PO29114	RAMPART	100	530	530
001 33-0036982-000	RES.,FXD MET. FILM 69.8K 1% 100PPM 1/8W	PO29115	RAMPART	100	530	530
001 33-0037689-000	RES.,FXD MET. FILM 76.8 1% 100PPM 1/8W	PO29117	MEPCO	300	531	531
001 33-0038451-000	RES.,FXD MET. FILM 8.45K 1% 100PPM 1/8W	PO29115	RAMPART	100	530	530
001 33-0039090-000	RES.,FXD MET. FILM 909 1% 100PPM 1/8W	PO29118	MEPCO	300	531	531
001 33-0039310-000	RES.,FXD MET. FILM 931 1% 100PPM 1/8W	PO29115	RAMPART	100	530	530
001 33-0039760-000	RES.,FXD MET. FILM 976 1% 100PPM 1/8W	II29004	MEPCO	300	529	
001 40-0702600-000	CAP.FXD CER RED CAP .01UF 10% WSR 50V	PO23616	ARROW	4	527	527
001 71-0714900-000	BRD.PRINTED WIRING 8658	PO31713	ECC	10	531	531
- -		PO31713	ECC	125	533	533
001 72-0557800-000	PIN.STRIP 36 PIECE	PO03473	BERG	1000	518	601
- -		PO03473	BERG	1000	514	601
- -		PO03473	BERG	1000	501	601
- -		PO03473	BERG	1000	510	601
- -		PO03473	BERG	1000	515	601
001 73-0134303-000	HEADER W/NUTS	PO31714	PMC	500	538	538
001 73-0480500-000	HEADER PLATE	PO31614	ENDICOTT	100	532	532
001 81-0703000-000	*I.C.D/A CONVERTER AD562JAD/BIN 12BIT	II2304203	ADS	15	529	
- -		XC2804203	ADS	15	526	531
001 82-0420102-000	*I.C.LINEAR SCDAD530K	II28332	ADS	25	529	
001 82-0565500-000	I.C.LINEAR 709	PO09676	SPARTAN	1000	520	601
- -		PO09676	SPARTAN	500	550	601
- -		PO09676	SPARTAN	1000	546	601
- -		PO09676	SPARTAN	1000	541	601
- -		PO09676	SPARTAN	1000	536	601
001 82-0729500-000	*I.C.LINEAR AD530S/883	PO23392	ADS	110	537	537
001 90-0900100-000	REF 90-67090 4.02K 1% 100PPM	PR5501400		100	537	537

Firm E

[redacted]

RUN DATE	5/28/73		PAGE	317
AS OF DATE	5/27/73	(INV982-05) FINISHED GOODS PROJECTION	WEEK	328

PART NO./MODEL	SERV CODE	QTY ON HAND	SAFETY STOCK	FACT L.T.	VEND L.T.	LOT SIZE	OOM	TRAN.	RET.	SHIP	ISSUE	ADJ
92-3868181-231							LAST WEEK					
DACBM	8	1	25	5	12	58	17	1	8	17	2	8

TRANSACTION DETAIL

TYPE	DESCRIPTION	QUAN	WK	DESCRIPTION	QUAN	WK	DESCRIPTION	QUAN	WK	DESCRIPTION	QUAN	WK
BK LOG	32161	34	327									
W I P	7257140 / .039	19	332	7257150 / .003	24	333	7257130 / .007	6	331	7257140 / .038	6	331
PL ORD	LOT NO 7257160	49	332	LOT NO 7257170	49	336	LOT NO 7257180	49	340	LOT NO 7257190	49	345
PL ORD	LOT NO 7257200	49	347									

TIME PHASED PROJECTION

WEEK	PAST	328	329	330	331	332	333	334	335	336	337	338	339	340
FORECAST		6	6	7	6	7	6	7	6	7	6	7	6	7
BACKLOG	34													
SCHD REC			4	14	11	7	14	5						
PLN RECS										18	29	18		18
PLN ORDS				49				49				49		
NEW NET	33*	39*	41*	34*	29*	29*	21*	23*	29*	26*	3*		6*	3*

WEEK	341	342	343	344	345	346	347	348	349	350	351	352	353	FUT
FORECAST	6	7	6	6	7	6	7	6	7	6	7	6	7	
BACKLOG														
SCHD REC														
PLN RECS	29	18		18	29	18			18	29	28	29	18	
PLN ORDS			49		49									
NEW NET	22	23	17	21	43	47	48	34	37	68	73	96	99	99

PLANNED ORDER ANALYSIS (NEW NET LESS SAFTEY STOCK) TOT FCST : 6.5/WK KIT SPREAD : 7.7

WEEK	PAST	328	329	330	331	332	333	334	335	336	337	338	339	340
DACBY	58*	64*	66*	59*	54*	54*	46*	43*	56*	51*	28*	25*	31*	28*
EXCEPT	*	*	*	*	*	*	*	*	*	*	*	*	*	*

WEEK	341	342	343	344	345	346	347	348	349	350	351	352	353	FUT
DACBM	5*	2*	8*	4*	18	22	15	9	12	35	48	71	74	74
EXCEPT	*	*	*	*								8	5	8

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Firm F

[redacted]

RUN DATE 5/28/73
AS OF DATE 5/27/73 (PL4920-03) FINISHED GOODS PROJECTION - COMBINED ANALYSIS - SUMMARY PAGE 14 WEEK 320

MODEL	WH ROOT	FUT NET LESS SS	EXCEPTION FLAGS (* : STK OUT) - : UNDER SS) $: TOO MUCH)	SERV. CO.
DAC120F	0516441	16	/** ******* / $$ /	B
DAC6M	0458101	74	/**************/**** $$$/	B
DAC12M	0465431	138	/$$ ** $$$$$$$$/$$$$$$$$$$$$$$/	AA
DAC8050D	0498533	16-	/**************/**************/	C
DAC8	0498391	153	*/* $$$$$$$$$$$$/$$$$$$$$$$$$$$/	B
DAC8ET	0495534	24	/*$$$$$$$$$$$$$/$$$$$$$$$$$$$$/	D
DAC6	0645201	79	/*$$$$$ / $ $$$$$$$$$/	AA
DAC8M	0499181	23	/ $$ / $$$$$$$ /	AA
DAC8MET	2499144	26	/** /$$$$$$$$$$$$$$/	C
DAC162MC8	2341806	18	/**************/************* /	B
DAC162MC8	9341841	16-	/**************/**************/	AA
DAC150MC8D	2341913	31	/ $$ / $$$$$$$$$$/	B
DAC8C8CSET	0615506	56-	/**************/**************/	C
DAC8C8CAD	0615548	13	/*********** / /	D
DAC1203C8	0615512	3	/******* / /	C
DAC1703C42T	0615523	51	/ $$/$ $$$$$$$/	B
DAC1215	0615531	47-	/**************/**************/	AA
DAC12LSC8ET	2615534	9	/ ***** / **** /	D
DAC1223C30	0615537	19	/******** / /	C
DAC1202C8	0340101	761-	/**************/**************/	AA
DAC1202C30	0340132	84-	/**************/**************/	AA
DACT	0499521	1	/*********** / /	C
DAC1021	4466641	2,242	/*****$$$$$$$$$/$$$$$$$$$$$$$$/	AA
DAC1023	0666682	419-	/********* ***/* **********/	AA

Firm G

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1816  0746                                                                                              176

WEEK NO.      0315    0322    0329    0405    0412    0419    0426    0503    0510    0517    0524    0531    BEYOND
QTY ORDERED
REQUIRED                12                                     27                               6
AVAILABLE      16-     28-     28-     28-     28-     55-     55-     55-     55-     61-     61-     61-     61-
*-*-*-*-*-*-*

PART NUMBER       DESCRIPTION        BALANCE    TOT REQ    SHORT    M/USE     EOQ    ROP    COST      CL SB LT    SS L/ACT.    ESC FOR.
 1816  0781       IC BIPOLAR                   ****-THIS PART HAS NO REQUIREMENTS-****        .00     D  P2 12    PR   /  /        1816  0781
*-*-*-*-*-*-*                                        BECAUSE IT HAS NO PARENT              O.K., NO OPEN ORDERS. P

PART NUMBER       DESCRIPTION        BALANCE    TOT REQ    SHORT    M/USE     EOQ    ROP    COST      CL SB LT    SS L/ACT.    ESC FOR.
 1816  0828       IC DIGITAL BI MEM               35                                            .00     D  P2 03    PR 12/10/5       1816  0828

WEEK NO.      PRIOR   1222    1229    0105    0112    0119    0126    0202    0209    0216    0223    0301    0308
QTY ORDERED
REQUIRED        12                              2                               8                               6
AVAILABLE      12-     12-     12-     12-     14-     14-     14-     14-     22-     22-     22-     22-     28-

WEEK NO.      0315    0322    0329    0405    0412    0419    0426    0503    0510    0517    0524    0531    BEYOND
QTY ORDERED
REQUIRED                                        5                               2
AVAILABLE      28-     28-     28-     28-     33-     33-     33-     33-     35-     35-     35-     35-     35-
*-*-*-*-*-*-*

PART NUMBER       DESCRIPTION        BALANCE    TOT REQ    SHORT    M/USE     EOQ    ROP    COST      CL SB LT    SS L/ACT.    ESC FOR.
 1816  0829       IC DIGITAL BI MEM               35                                            .00     D  P2 03    PR 12/10/5       1816  0829

WEEK NO.      PRIOR   1222    1229    0105    0112    0119    0126    0202    0209    0216    0223    0301    0308
QTY ORDERED
REQUIRED        12                              2                               8                               6
AVAILABLE      12-     12-     12-     12-     14-     14-     14-     14-     22-     22-     22-     22-     28-

WEEK NO.      0315    0322    0329    0405    0412    0419    0426    0503    0510    0517    0524    0531    BEYOND
QTY ORDERED
REQUIRED                                        5                               2
AVAILABLE      28-     28-     28-     29-     33-     33-     33-     33-     35-     35-     35-     35-     35-
*-*-*-*-*-*-*

PART NUMBER       DESCRIPTION        BALANCE    TOT REQ    SHORT    M/USE     EOQ    ROP    COST      CL SB LT    SS L/ACT.    ESC FOR.
 1820  0054       IC  7400 GATE        5902      35501               322              OMP3     .14     A  P2 16        12/17/5       1820  0054

WEEK NO.      PRIOR   1222    1229    0105    0112    0119    0126    0202    0209    0216    0223    0301    0308
QTY ORDERED    896-175829
                      5000-179864
                                              5000-178737
                                                              5000-180416
REQUIRED       2790    4110    1181     554    1408    3676    1320     389    1520    3629    1792     552    1300
AVAILABLE      4008    4898    3717    3163    6755    3079    6759    6370    4850    1221    571-   1123-   2423-
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DEPT-1700262
DATE-04/10/76

LINE SHORTAGE/PRESHORTAGE LISTING

PAGE 6

INSTRUMENT	RUN #	PART #	DESCRIPTION	QTY REQ'D	QTY SHT* PRESHT	DATE REQUIRED	ESTIMATED COVERAGE	ON-HAND STOCK	QA STOCK	CNTRL	ALTERNATE DELIVER-TO
96323	17132592	07830-60400	PCB,ECG BUFFER	75	0*	03/18/76	**/**/**	5	0	66	
8030A*50	17132521	5060-9802	HANDLE STRAP	40	40*	03/25/76	04/12/76	0	0	16	
		9270-0485	PAPER-CHART	12	12*	03/26/76	04/16/76	0	0	18	
		9270-0485	PAPER-CHART	12	12*	03/29/76	04/16/76	0	0	18	
		05216-40070	DECK	60	23*	04/01/76	04/09/76	0	0	15	
		08030-66503	PCB,ABD,ECG	13	4*	03/09/76	**/**/**	0	0	66	
		15270-60001	KIT,DIRECT,ECG	20	20*	03/29/76	04/14/76	0	0	13	
		15276-60001	KIT,INTRNL LABOR	18	18*	03/26/76	04/14/76	0	0	13	
	17132522	5021-0504	TAPE,DISTANCE	15	15*	04/08/76	04/13/76	0	0	16	
		5060-9802	HANDLE STRAP	30	30*	04/05/76	04/12/76	0	0	16	
		5060-9845	COVER BOTTOM	15	12*	04/05/76	04/12/76	0	0	16	
		8120-1992	CABLE ASSY 6 FT	15	0*	04/08/76	**/**/**	16	110	10	
		9270-0485	PAPER-CHART	15	15*	04/06/76	04/16/76	0	0	18	
		9270-0485	PAPER-CHART	15	15*	04/09/76	04/16/76	0	0	18	
		05216-40070	DECK	60	60*	04/05/76	04/09/76	0	0	15	
		08030-66501	PCB,LOGIC	15	8*	04/08/76	**/**/**	0	0	66	
		08030-66502	PCB,TRIGGER	15	8*	04/08/76	**/**/**	0	0	66	
		08030-66503	PCB,ABD,ECG	8	8*	04/08/76	**/**/**	0	0	66	
		08030-66504	PCB,DIRECT ECG	15	8*	04/08/76	**/**/**	0	0	66	
		08030-66505	PCB,ULTRASOUND	15	8*	04/08/76	**/**/**	0	0	66	
		08030-66506	PCB,BRIGHT SCO	15	9*	04/08/76	**/**/**	0	0	66	
		08030-66513	PCB,PHONO AMP	2	2*	04/08/76	**/**/**	0	0	66	
		08030-66521	PCB,CONNECT	15	15*	04/08/76	**/**/**	0	0	66	
		08030-66522	PCB,SENSING	15	15*	04/08/76	**/**/**	0	0	66	
		08030-66523	PCB,SENSING	15	15*	04/08/76	**/**/**	0	0	66	
		08030-66524	PCB,SERVO	15	15*	04/08/76	**/**/**	0	0	66	
		08030-66525	PCB,CHART PEN	15	15*	04/08/76	**/**/**	0	0	66	
		14162A	CABLE,GND	15	0*	04/08/76	**/**/**	0	0	67	
		15270-60001	KIT,DIRECT,ECG	15	15*	04/08/76	04/14/76	0	0	13	
		15276-60001	KIT,INTRNL LABOR	12	12*	04/05/76	04/14/76	0	0	13	
8030A*50-#K	17306623	15272-60001	PHONO X-DUCER	5	5*	03/12/76	04/14/76	0	0	13	
	17306627	08030-61602	CABLE,LABOR	9	9*	03/12/76	**/**/**	0	0	67	
		08030-61603	CABLE,HEART RATE	9	9*	03/12/76	**/**/**	0	0	67	
		08030-66508	PCB,DVM	9	9*	03/15/76	**/**/**	0	0	66	
		08030-66510	PCB,PWR SUPPLY	9	9*	03/15/76	**/**/**	0	0	66	
		08030-66522	PCB,SENSING	9	9*	03/15/76	**/**/**	0	0	66	
		08030-66524	PCB,SERVO	9	9*	03/15/76	**/**/**	0	0	66	
		08030-66525	PCB,CHART PEN	9	9*	03/15/76	**/**/**	0	0	66	
		08030-66561	PCB,LARGE EXT	9	4*	03/16/76	04/14/76	0	0	13	

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CONTROLLER--OUTZEN --14 CONTROLLER SHORTAGE/PRESHORTAGE LISTING PAGE 2
04-09-76

PART #	ON-HAND STOCK	QA	PARENT #	RUN #	AREA #	QTY SHT* PRESHT	DATE REQUIRED	QUANTITY	DATE SHP* CONFIRMED	ORDER	CRPS PRIORITY
2100-2686	0	0						175	04-12-76*	17182464	
								125	07-05-76*	17184019	
			TOTAL	**************		21					
3100-1882	0	0	08806-61011	17280967	1700226	0*	03-16-76	10			
			02167	17281038	1700226	11**	04-09-76	11			
								50	04-09-76	17182680	
								50	05-03-76*	17183182	
			TOTAL	**************		11					
3100-2236	0	0	02167	17133332	170026C	22*	04-08-76	22			
								60	04-19-76*	17182418	
								65	05-03-76*	17183005	
								60	05-31-76*	17184180	
			TOTAL	**************		22					
3100-2274	0	0	01500-60302	17132406	170025D	50*	03-29-76	125			
			15008-MPCN	17115099	1700271	15*	04-05-76	15			
			01511-60302	17132805	170025D	60*	04-07-76	60			
			15118-609	17132805	170025D	20*	04-08-76	20			
								250	04-12-76	17182682	
								250	05-24-76*	17182682	
								250	05-24-76*	17183181	
								500	06-14-76*	17184025	
								250	07-12-76*	17183181	
			TOTAL	**************		145					
3101-0986	104	0	14060K	17250689	170026C	0*	03-22-76	154			
			14060K	17248703	170026C	0*	04-05-76	152			
								100	05-03-76*	17183185	
								150	06-07-76*	17183185	
3101-1047	0	0	01514 63300	17281238	1700222	42*	03-11-76	49			
			91268	17	1700259	10*	03-20-76	10			
			01294	17	1700259	10*	04-06-76	10			
								150	04-09-76	17181357	
								250	04-12-76*	17182684	
								100	06-14-76*	17183183	
								150	06-14-76*	17184179	
			TOTAL	**************		62					
3980-0310	0	129	07754-60340	17261336	170025F	0*	03-22-76	380			
								260	04-09-76	17180788	
								40	02-09-76*	17181724	
								500	03-29-76*	17181724	
								500	05-17-76*	17183305	

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PART NUMBER	DESCRIPTION	ACCT	CT LR	ORDER NUMBER	ORDER QTY	RECVD QTY	JOB NUMBER	OLD BALANCE	WANTED QTY	ISSUE QTY	COMP BALANCE	AREA	RE SP	REMARKS
1910-0016	DIODE GE	1310	19	17281040			08803-60020		106	106	5934	1700A22	14	PLANNED ISSUE
1910-0016	DIODE GE	1310	19	17281042			08808-60030		72	72	5862	1700A22	43	PLANNED ISSUE
1910-0016	DIODE GE	1310	19	17888888			01024		15	15	5847	1700225	41	UNPLANNED ISSUE
1932-0057-5	TUBE EL PHE CULL	1310	17	17248589			00610		500		0	1700431	17	UNPLANNED ISSUE
1970-0039	ELECTRON TUBE	1310	17	17181792		1000					1669			STOCK RECEIPT
1970-0039	ELECTRON TUBE	1310	17	17888808			92314		20	20	1649	1700262	58	UNPLANNED ISSUE
1970-0044	SPARK GAP	1310	17	17			91344		2	2	1460	1700228	12	UNPLANNED ISSUE
1990-0325	LAMP,SOLID STATE	1310	19	17871922			01240		1	1	719	1700246	41	UNPLANNED ISSUE
2090-0030	TUBE CATHODE RAY	1310	17	17		1					279	1700431	19	CREDIT
2090-0030	TUBE CATHODE RAY	1310	17	17888888			06581		1	1	278	1700431	19	UNPLANNED ISSUE
2090-0035	TUBE CATHODE RAY	1310	17	17182715		69					64			STOCK RECEIPT
2090-0035	TUBE CATHODE RAY	1310	17	17306256			01240		1	1	83	1700246	33	UNPLANNED ISSUE
2090-0035	TUBE CATHODE RAY	1310	17	17998838			IPK-12-94838		25	25	58	1700282	52	UNPLANNED ISSUE
2090-0035	TUBE CATHODE RAY	1310	17	17987963			IPK-12-87963		217	217	0	1700282	52	ISSUE MORE THAN BOM UNPLANNED ISSUE
2100-0558	RES 20K 10%	1310	14	17181400		1425					3303			STOCK RECEIPT
2100-0558	RES 20K 10%	1310	14	17888888			01024		15	15	3288	1700225	17	UNPLANNED ISSUE
2100-0942	RES VAR 50K 3/4W	1310	14	17281044			01513-62600		15	15	89	1700Y22	14	PLANNED ISSUE
2100-0942	RES VAR 50K 3/4W	1310	14	17				99	89		89	1700	14	INVENTORY ADJUSTMENT
2100-1966	RES VAR 20K 20%	1310	14	17280953			02133		2	2	147	1700228	47	UNPLANNED ISSUE
2100-2030	RES VAR 20K 1/2W	1310	10	17280052			01229		50	50	1484	1700224	17	UNPLANNED ISSUE
2100-2030	RES VAR 20K 1/2W	1310	10	17281269			01079		4	4	1480	1700222	41	UNPLANNED ISSUE
2100-2066	RES VAR 2K,5W CU	1310	10	17939515			IPK-22-39515		50	50	790	1700282	11	UNPLANNED ISSUE
2100-2464	RES VAR 20K 1W	1310	14	17888888			06157		20	20	644	1700224	41	UNPLANNED ISSUE
2100-2892	RES VAR 2500 1/2	1310	10	17281256			00461		95	95	99	1700222	24	UNPLANNED ISSUE
2100-2911	RES VAR 10K 1/2W	1310	14	17182455		900					1678			STOCK RECEIPT
2100-2911	RES VAR 10K 1/2W	1310	14	17281266			00461		95	95	1583	1700222	24	UNPLANNED ISSUE
2100-2911	RES VAR 10K 1/2W	1310	14	17888888			01461		10	10	1573	1700224	41	UNPLANNED ISSUE
2100-3089	RES VAR 5K 10%	1310	14	17601939			96852		4	4	23	1700534	41	UNPLANNED ISSUE
2100-3252	RES 5K 10% MI	1310	14	17282871			08030-66505		50	50	1898	1700222	24	PLANNED ISSUE
2100-3252	RES 5K 10% MI	1310	14	17281268			01079		1	1	1897	1700222	41	UNPLANNED ISSUE
2100-3540	RES VAR	1310	10	17871922			01240		1		0	1700246	41	UNPLANNED ISSUE

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MATERIAL REQUIREMENTS PLANNING

A STUDY

by

Ajit Surajmal Kanodia

B. TECH., Indian Institute of Technology, Bombay

(1973)

SUBMITTED IN PARTIAL FULFILLMENT

OF THE REQUIREMENTS FOR THE

DEGREE OF MASTER OF

SCIENCE

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

June, 1976

Signature of Author...
Alfred P. Sloan School of Management, May 7, 1976

Certified by...
Thesis Supervisor

Accepted by..
Chairman, Departmental Committee on Graduate Students

MATERIAL REQUIREMENTS PLANNING
A STUDY

by

Ajit Surajmal Kanodia

"Submitted to the Alfred P. Sloan School of Management on May 7th, 1976 in partial fulfillment of the requirements for the degree of Master of Science."

Inventory management techniques have gained in importance in the past few years because of the cash crunch being faced by most companies. Material Requirements Planning (MRP) is gaining rapidly in popularity, specially after the APICS (American Production and Inventory Control Society) MRP Crusade. The technique is being presented as if it were the cure for all ills. The purpose of this thesis is to identify a number of issues that are relevant to MRP and, wherever possible, to propose an approach. Another purpose is to study how firms tackle these issues and to present real-life implementation characteristics. With this in mind, seven firms were interviewed personnaly. The study concludes that the issues are largely unresolved in industry and whatever benefits are accruing are mostly due only to better timing information generated by the explosion process rather than any other formal procedures. It follows that further benefits are achievable if the issues are tackled in a scientific manner.

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Title: Assistant Professor of Management Science